Energy Research and Development Division
FINAL PROJECT REPORT

CANBY GEOTHERMAL DEVELOPMENT PROJECT

GRDA Final Project Report

Prepared for: California Energy Commission
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PREFACE

The California Energy Commission Energy Research and Development Division supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

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The Canby Geothermal Development Project is the final report for the Canby Geothermal Development Project, Contract Number GEO-07-001, conducted by Modoc Contracting Company. The information from this project contributes to Energy Research and Development Division's Renewable Energy Technologies Program.

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ABSTRACT

This well drilling and testing project is part of the Canby Geothermal Development program, a community-based geothermal development project in Canby, California (Modoc County). The current project drilled a 3,852 ft. geothermal well to identify and evaluate local geothermal resources. This report covers the drilling and testing of the ISO-2 geothermal well in Canby. Notable highlights of the findings from the well drilling and testing include:

- ISO-2 well drilled in two phases.
- Well Depth: 3,852 feet
- Resource Temperature: 205°F
- Injection Index: 1 gallon per minute/pounds per square inch gpm/psi
- Slotted liner installed where permeable formations exist

Drilling the ISO-2 well provided two important benefits for California rate payers:

1. An injection well to dispose of fluids from the production the ISO-1 and future ISO-3 geothermal wells, and
2. Drilling data that furthers the understanding of the Canby Geothermal Field for future exploration to generate renewable power.

Keywords: GRDA, geothermal, direct-use, drilling, renewable, cascaded system, net-zero energy, sustainable, distributed generation, power, community-based

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EXECUTIVE SUMMARY

Introduction and Background

This project is a part of the larger Canby Geothermal Development Project (Canby Project), a community-based geothermal development project. It continues an earlier project, the I'SOT District Heating Demonstration Project, completed in 2004, that was selected for funding by the Geothermal Resources Development Account Program. At that time, a 2,100 ft. geothermal well was drilled that provided enough energy to support 67,000 square feet (ft^2) of homes and businesses with space heat and domestic hot water. Project partners the U.S. Department of Energy (U.S. DOE) and the National Renewable Energy Laboratory assisted with well drilling, engineering, and installation funds to capture more completely the marginal geothermal resource of 37 gpm at 250 ft. of drawdown.

Currently, the district heating system space heats over 70,000 ft^2 and supports California's first geothermal laundromat on only 16 gallons per minute (gpm) annual average from a geothermal resource.

This project received funding to drill a 4,000 ft. geothermal production well into a nearby fault to produce geothermal fluids for power production and several direct-use applications. This exploration fits within a plan to create the first completely sustainable net-zero-energy community in California by fully using or "cascading" a geothermal resource to 1) produce green electrical power for California ratepayers; and 2) create up to 120 jobs by implementing several geothermal direct-use applications that include greenhouse and aquaculture operations. To cascade the resource would be to extract heat from it and reduce its temperature in stages, so that several processes make use of the heat at successive temperatures.

Purpose

Geothermal Resources Development Account funding was used for this project to find additional geothermal resources to sustain a cascaded geothermal system that would generate power and support several direct-use applications.

Objectives

The goal was to drill a 4,000-ft. geothermal production well to intersect a local fault and evaluate the resource potential for use for long-term power production. A successful well and subsequent injection would have addressed an environmental issue with the existing district heating system by ending geothermal discharge to a local river. Such an outcome would have also increased the capacity of a district heating system, allowing additional cascaded uses and furthering the understanding of Canby's geothermal resource for continued development.

Conclusions

The resulting ISO-2 well drilling did not intersect the anticipated fault at the anticipated depth, but this work gave more information to assist in planning further development. Highlights of the information obtained were:

- The maximum local resource temperature is 205°F.
- All of the alteration documented is consistent with relatively recent interaction with low

(<200°C) temperature hydrothermal fluids. There is no indication that these rocks have experienced a previous higher temperature alteration episode that may indicate that the Canby resource is a young emerging geothermal system rather than an old system that is in decline. The alteration is the hardening of a formation by fluids of a higher temperature and pressure. An ISO-2 pressure-temperature survey showed an isothermal gradient of more than 1000 ft., which suggests a classic convective temperature profile. This profile suggests that the ISO-2 well is at the edge of a convective cell of a geothermal reservoir which will be helpful information in further development of the Canby Geothermal Field.

- There were five zones (over 800 ft.) shown by the electric logs that may be developed to enhance future geothermal injection.

The well did not meet a predefined criterion to generate at least 280 kilowatts (kW) of power and was determined to be not productive enough to justify spending Energy Commission funds on subsequent project tasks.

Geophysical work (magnetotelluric survey-MT) was completed in the Canby area in March 2012 to further understand and develop the local geothermal resource. MT is an electromagnetic geophysical method of imaging the earth's subsurface by measuring natural variations of electrical and magnetic fields at the Earth's surface A subsequent ISO-3 geothermal well was sited according to all available data in fall 2012.

Recommendations

It is recommended that a magnetotelluric survey be conducted over the suspected fault structures in the Canby area to understand further the geothermal system underlying the town. It is important to understand where the possible upflow faults are located as well as areas of greatest permeability to advance the development of this geothermal resource. An upflow fault is a fracture in the earth that allows hot geothermal water to ascend from great depth.

Lessons learned from the results of the ISO-2 well can be compared to ISO-1 that was drilled in 2000 for the existing district heating system. In each case, there is a formation starting at 2,100 ft. that showed permeability but is easily damaged via mud rotary drilling methods, with mud rotary method being defined as a method of drilling that uses bentonite drilling mud as the lubricant for drilling. Future drilling in the Canby area may include drilling with a reverse circulation drilling rig through 1,500-2,000 ft. of smectite clay formations and drilling with air below 2,100 ft. until the 205°F resource has been identified. A variation of the rotary drilling method in which the cuttings are pumped up and out of the drill pipe, an advantage in certain large diameter holes.

Development of the ISO-2 well will include surging the well by injecting air in 100 ft. stages and letting the well recover after each event down to a depth of 1400 ft. Surging a well is to stimulate it hydraulically in order to study the response of the reservoir or rock properties. When a well recovers, it returns over time to one or more equilibrium conditions. This method will increase the hydraulic pressure in 800 ft. of low-permeability formations in the well between 2060-3850 ft. to

release the drilling mud. The drilling mud that was deposited on the sides of the well may reduce productivity or injectivity of the well.

The Canby Project will continue to develop the geothermal resource in Canby under a U.S. DOE grant to develop a cascaded geothermal system with the data and lessons learned from drilling the ISO-2 geothermal well.

Benefits to California

The benefits to California from the present project are a greater understanding of the geothermal resource in Canby. The Geothermal Resoruces Development Account Program helped project developers further understand Canby's geothermal resource. Further development will be beneficial to not only the Town of Canby by providing energy and jobs, but to more than 71 colocated small communities in California looking to develop local resources.

.CHAPTER 1: Introduction

In February 2008, Modoc Contracting Company, on behalf of a community-based geothermal development project, submitted a proposal to the Energy Commission's GRDA Program to drill a 4,000 ft. geothermal production well and supply the energy from that effort to produce power and cascade the remaining energy to support an existing geothermal district heating system and future greenhouse and aquaculture businesses. Cascading geothermal energy involves using thermal heat to first generate electrical power, and then using the subsequent fluids for direct-use applications of energy need. If successful, Canby would be the first net-zero community in California. In June 2008 the Canby Project secured funding. Tasks 1.1 and 1.2 in the 2008 funding agreement were to permit and provide match funding to drill the proposed ISO-2 geothermal well.

A California Environmental Quality Act (CEQA) review was started in January 2009, completed in September 2009, and a subsequent contract was signed with the Energy Commission in February 2010. A Modoc County Use Permit was obtained in May 2010 to proceed with the proposed project tasks.

In 2009, American Recovery and Reinvestment Act funding supported energy investments and $400,000 was funneled into the national geothermal program to advance the use of geothermal technologies. A two phase approach was developed to spread the cost of drilling out over a longer period of time. Blow-out prevention equipment (BOPe) was not required during Phase 1 drilling activities, saving some money and allowing for another rig that was being developed to drill at a later time.

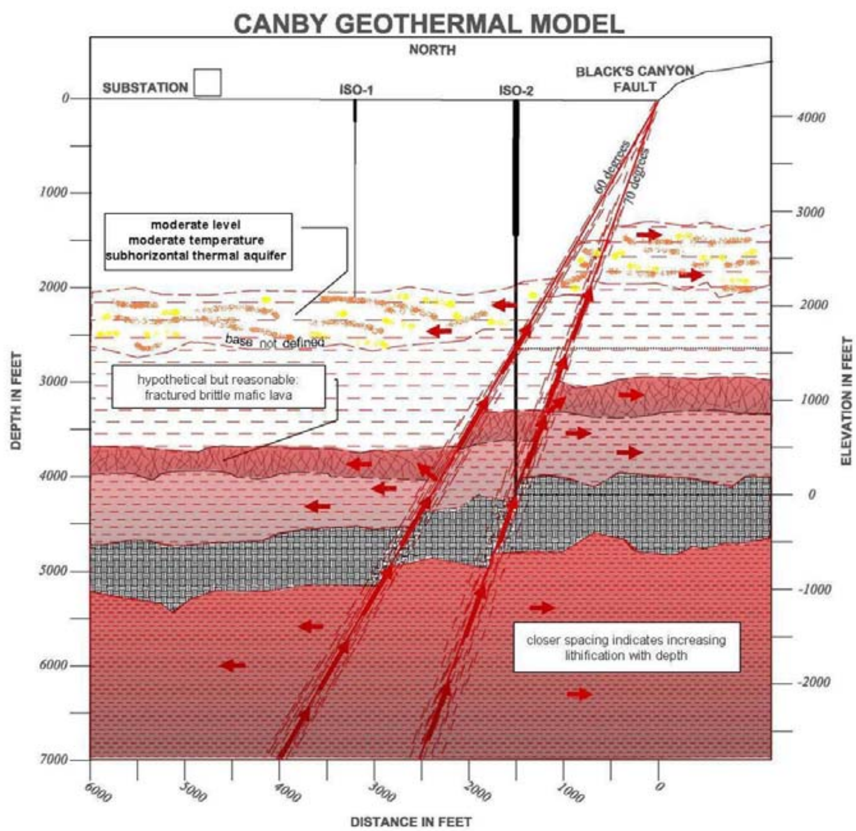
Both phases of drilling and well testing were completed during 2011.

CHAPTER 2: Objectives

The objective of this project was to drill a 4,000-ft. geothermal production well to intersect an identified local fault (Figure 1) and evaluate the potential for long-term power production. Additionally, a successful well and subsequent injection would mitigate an environmental issue with the existing district heating system by ending geothermal discharge into a local river. Such an outcome would have also increased the capacity of a district heating system, allowed additional cascaded uses, and furthered the understanding of Canby's geothermal resource for continued development.

These objectives would have been achieved by producing enough geothermal resource with adequate temperature and flow. The metric for success was to develop enough resource to produce 280 kW of electrical power.

Figure 1: Canby Geothermal Model



CHAPTER 3:
Method and Course of Work

3.1 Drilling and Flow Test Plan

The drilling and flow test plan was provided by the project drilling engineer, Steve Pye, designer and driller of the largest geothermal well in the world – Vonderahe 1, a 50 MW geothermal producing well in the Salton Sea KGRA.

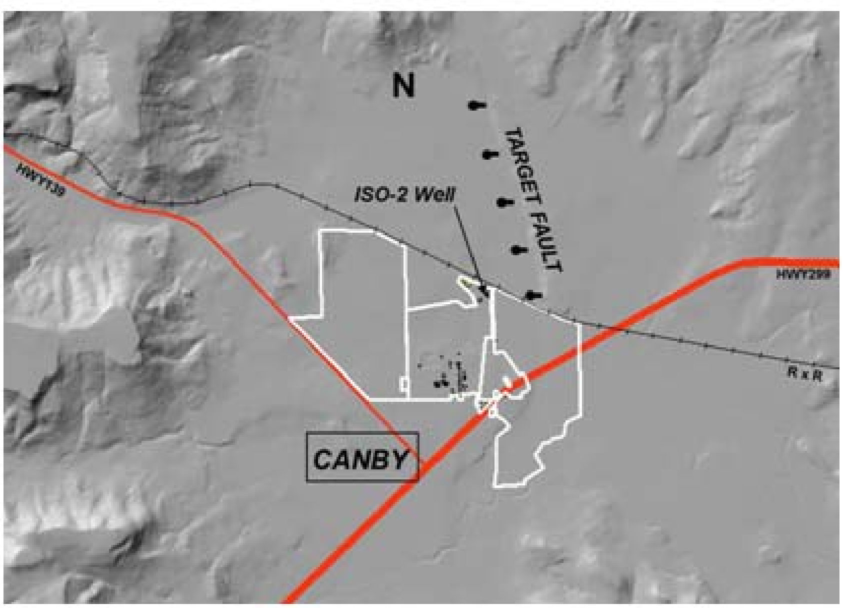
The ISO-2 geothermal producing well was planned to be drilled in Canby (Figure 2) in two phases and tested for power producing potential. A 250 by 250 ft. drilling pad was to be constructed and a lined containment basin installed. A 4,000 ft. well was intended to intersect a local fault, expected to be dipping at a 60-70° angle, at depth.

Drilling was to be done in two phases:

- Phase 1, drilling, casing, and cementing 13-5/8 in. surface casing to 1500 ft.
- Phase 2, drilling a 12-¼ in. hole to 4,000 ft. and installing a 9-5/8 in. liner

A subsequent well flow test was planned to determine long term productivity and power generating potential. A predetermined benchmark for success was for the well to deliver enough flow and temperature to generate 280 kW of electricity.

Figure 2: Project Site Location

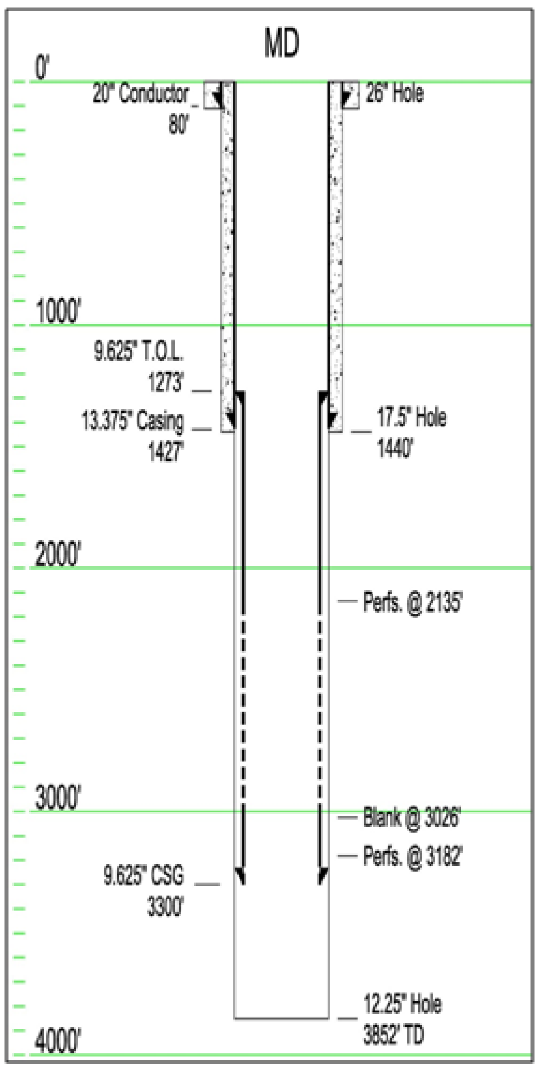


3.2 Drilling

The Canby Project entered into a contract with Hydro Resources (Hydro) in February 2011 to drill the ISO-2 well. Hydro is a large water well drilling company based in Houston, TX. Hydro's company vision includes drilling low temperature, moderate depth, geothermal wells at a community level. The Canby Project was to be their first drilling project of this type.

Drill cutting samples were collected at 10-foot intervals during the drilling of the ISO-2 well. The cuttings were logged and described by use of a 10X to 60X zoom binocular microscope by professional mud loggers and by geothermal geologists Joe LaFleur and Mike Krahmer. Rock color was correlated to GSA rock color chart; carbonate content was checked with 10 percent HCl; magnetite was routinely checked for; and a steel probe was used to determine hardness. The ISO-2 well schematic is seen in Figure 3.

Figure 3: ISO-2 Well Schematic



3.2.1 Phase I

The drilling pad was constructed to specifications, approximately 250 feet by 250 feet with a containment basin measuring 100 feet by 60 feet by 5 foot deep. The pad was sloped to allow any fluids to drain into the containment basin.

The community in Canby came out on a Sunday afternoon and installed the containment basin liner as shown in Figure 4. This involved removing all rocks and debris that would cause a perforation in the EPDM membrane. The membrane had been previously spliced and folded before the final event of unfolding and stretching the liner in place. This was a great way to get the community involved in the project and produced a sense of ownership. The liner installation took about an hour and a half.

Figure 4: Installing EPDM Liner

Phase 1 of the drilling program began on February 28, 2011 and finished the surface portion of the ISO-2 geothermal well during the first week of March. The hole was drilled to 1440 feet, and 13.375 inch surface casing was successfully landed and cemented. The casing shoe was placed at a competent formation at 1427 ft. depth. The top part of the well was drilled with a reverse circulation rig in adverse conditions.

The drilling company also accepted the addition task of giving tours to a high school class and other Canby community members during the drilling process as shown in Figure 5. Extra care was also given to ensure that this part of the well casing was straight and .hole deviation was kept below 1° to 1440 feet.

Figure 5: Phase 1 Drilling: Tour for High School Students

3.2.2 Phase II

Phase 2 drilling started again during the first week in September 2001 and the 2425′ of 12.25″ hole was accomplished in 8-24 hour days (Figure 6). In the upper section from 1440′ to 2150′, clay clogging the flow line, and plugging of the shakers was a problem that limited progress at times. The project drilling supervisor reported swelling clays encountered from 1535′ to 1735′, and they tripped out of the hole to treat the mud and raise its weight from 8.7 ppg to 9.3 ppg. Increasing solids in the mud resulted in the mud-weight going from 9.3 ppg to a 9.6 ppg at the bottom of hole despite periodic dumping of the sand trap. Despite the higher mud-weight, no loss circulation was observed at any time during the drilling of this hole. Hole deviation was kept below 3° up to 3118′. The survey at 3407′ was 7° as a result of increased WOB (weight on bit) and perhaps some contribution by the formation. WOB was reduced, and coupled with the increased hardness of the basaltic andesite at the bottom of the hole, the rate of penetration (ROP) (was significantly lower for the interval between 3450′ and 3852′ total depth (TD). The final deviation survey at 3812′ was 2° off vertical.

Figure 6: Phase 2 Night Drilling ISO-2

3.3 Well Testing

After the well was drilled, it was clear that no major encounters with open formations had occurred because there was no loss of drilling fluid. The mud-out temperatures did not provide any hope for targeted temperatures at depth, and the cuttings gave no indication that a significant hydrothermal system had been encountered. Finally, after the open-hole electric log measurements showed limited temperatures and fractured rock, a decision was made about a cost effective way to determine the ability of the rocks encountered to accept or produce fluids. This option was injection testing. The planned flow test was not considered an option since the available data at the time gave little hope that the more expensive flow test would be cost effective.

The decision to carry out an injection test was made by the project reservoir engineer, Paul Atkinson in collaboration with the entire Canby Project team.

The rig injection test was run on September 14. Open-ended drill pipe was run into the hole to 1126 ft. and surface water at approximately 50° F was injected. The rate was increased in a step-wise fashion, and surface annulus pressure at the wellhead was measured through one of the 13 3/8 in. casing head outlets.

Injection increased until a maximum surface pressure of approximately 350 psig was reached after 27 minutes at an injection rate of 337 gpm. This rate was held for another 25 minutes, at which time the water supply in the tanks ran out and injection was stopped.

3.4 Later Tasks Planned as Part of Project

If the productivity of the ISO-2 geothermal well had supplied enough energy to produce 280 kW of electrical power, other tasks under the Energy Commission contract would have been possible:

- Plans to install a 2900 ft. pipeline to the ISO-1 well for re-injection.
- Retrofit existing mechanical equipment in the district heating Central Plant for expansion.
- Discontinuing a geothermal discharge under an existing National Pollutant Discharge Elimination System (NPDES) permit to a local river.

CHAPTER 4: Results and Discussion

The results from the drilling of the ISO-2 geothermal well and subsequent injection test were a first approximation of the well injectivity, with an estimated injectivity index of approximately 1 gpm/psi. It needs to be stressed, though, that this result has been derived from a very short test during which most individual rates only occurred for a few minutes. Thus, longer-term injection in the well might have different characteristics. The injectivity index, converted to a production index shows the productivity of the ISO-2 well would be about 160 gpm with approximately 500 ft. of drawdown in the well. Clearly though, the overall injectivity or productivity of the ISO-2 geothermal well is limited. Appendix B contains the injection test procedure, results and interpretation of the data collected.

While the results from the ISO-2 drilling did not meet expectations, the utility of the well needs to be put into perspective. The ISO-1 well, that now supports a geothermal district heating system, supplies energy and domestic hot water for 70,000 ft^2 residential, agricultural, and commercial structures uses only 16.6 gpm annual average of 190°F geothermal water. Therefore, the ISO-2 geothermal well has ten times more capacity than the ISO-1 well. A community-based geothermal development project will view well success differently from a company drilling a well solely for the purpose of generating large scale power.

Another pressure-temperature survey was conducted 35 days after the drilling operations concluded, when the well was expected to have come to equilibrium. The temperature gradient was the same as the first ISO-1 geothermal well, drilled in 2000, with a maximum temperature of 205° F. However, the well was essentially isothermal for approximately 1,000 ft., from 2300-3300 ft. showing a classic convective profile according to Dr. William Glassley. Dr. Glassely believes that there is a heat source under Canby, somewhere at depth, driving this phenomenon. Dr. Glassely has more than 35 years of experience in the analysis, modeling, and evaluation of geological processes that drive geothermal systems.

The lessons learned in 2000 when the first ISO-1 geothermal well was drilled were that a geothermal resource in Canby is below 2100 ft. and that a driller will encounter 2000 ft. of smectite clay/tuff requiring an appropriately sized drilling rig. Further, the somewhat permeable formation between 2048-2100 ft. was easily damaged with drilling mud.

The first two lessons were used in planning the ISO-2 geothermal well under this contract. The ISO-2 well also encountered the same smectite clay/tuff formations and the first permeable formation started at 2100 ft. Instead of a small drilling rig that took one month to drill 2100 ft., the selected rigs for this well only took 6 days. However, the lesson of the somewhat permeable formation around 2100 ft. was ignored because the ISO-2 drilling plan anticipated intersecting the open fractures of a local fault at a greater depth, which didn’t occur. It is believed today that the Black’s Canyon Fault could be near vertical, but a scheduled geophysics survey is needed to make that determination. A near-vertical orientation of the fault has been suggested by project geologist Joe LaFleur and James Faulds of UNR.

The drilling plan for a proposed ISO-3 well now recognizes the value of maximizing the formation below 2100 ft.. Drilling with a reverse-circulation rig to that approximate depth then drilling with air until that formation is fully exploited looks like the path forward at this time. After max temperature of 205°F in both ISO-1 and ISO-2 wells at that depth, typical BOPe would also not be needed.

The need for a geophysical survey will also be used to site the ISO-3 well. Hydro Resources has a subsurface imaging team that uses magnetotelluric (MT) survey technology. This technology will be used to verify the dip of the fault that the ISO-2 well was targeting. After these data are gathered, a revised geologic model will be constructed.

While subsequent project tasks will not be funded under the current project, the ISO-2 well is targeted for further development. The well is planned to be used as an injection well after efforts are made to increase injectivity.

A community-based cascaded geothermal development project such as the Canby Project has received support from the GRDA Program to pave the way for developing resources of many other small communities in California and other places where co-located geothermal resources exist. The public is beginning to become aware of the value of cascaded geothermal projects due to the progress of the Canby Project. A Reuters piece, re-printed from a Cleantechnica article in 9/23/2010 stated:

> **Cascading Geothermal Energy Could Revive Small Towns with Green Jobs**
>
> Oddly enough a religious community called I'SOT in Canby, California provides a textbook example of a cascading geothermal project, which is under development in partnership with the Department of Energy and the National Renewable Energy Laboratory. In 2006 the community began operating a geothermal heating system that provided heat and heat and hot water for 34 buildings, but the effluent from that operation was simply filtered and discharged to a river. Under the new project, the highest-temperature fluid will be used to generate electricity. After that, energy can still be extracted for additional space heating and hot water, operating up to ten acres of greenhouses, heating up to four 30-foot diameter aquaculture tanks, and for melting snow. The system may also provide enough energy to operate a new food storage and laundry facility.
>
> The Modoc Contracting Company - also of Canby - won the DOE grant, receiving \$2 million out of a larger \$20 million grant for job-creating, innovative geothermal technology that was shared among six other projects. That \$2 million is a modest amount compared to the impact it could have on communities across the U.S., as DOE estimates that in the west alone there are about 1,500 possible well sites in small towns and mid-sized cities with the potential to develop cascading geothermal projects. That in turn could create new green jobs in local aquaculture and greenhouse-based agriculture operations.”

Further, the Canby Project was used as a case study in a renewable energy textbook. In Glassley, W., 2010, *Geothermal Energy, Renewable Energy and the Environment,* (CRC Press), the textbook showcases the Canby Project for potential engineering students studying renewable energy. Energy Commission support has helped this project to receive national recognition. It has also increased public awareness of the advances in renewable energy and in cascaded geothermal systems in particular.

4.1 Drilling Technology Transfer

Several tours have been given to the public since the ISO-2 was drilled. Tours will continue as requests come in for such events.

On July 1st of 2012, the University of Reno's Geothermal Academy is scheduled to Canby and tour the facility.

A project paper was written and presented at the Geothermal Resource Council in October 2012 in Reno, NV.

CHAPTER 5: Conclusions

Conclusions about the work funded in this project can be summarized as:

ISO-2 well drilling did not intersect the anticipated fault at depth but gave more information to plan further development. The maximum local resource temperature is 205°F.

All of the alteration documented is consistent with relatively recent interaction with low (<200°C) temperature hydrothermal fluids. There is no indication that these rocks have experienced a previous higher-T alteration episode, which may indicate that the Canby resource is a young emerging geothermal system rather than an old system that is in decline.

An ISO-2 pressure-temperature survey, which shows an isothermal gradient of over 1000 ft. suggests a classic convective temperature profile.

There were five permeable zones (over 800 ft.) shown by the electric logs that may be the target of future hydro-shearing activities.

The well did not meet the predefined criterion to generate at least 280 kW of power, and was therefore not productive enough to expend Energy Commission funding on subsequent project tasks. Geophysical work (magnetotelluric survey) will be completed in the Canby area in March 2012 to further understand and develop the local geothermal resource. A subsequent ISO-3 geothermal well will be sited according to all available data in fall 2012.

CHAPTER 6: Recommendations

The first recommendation is to encourage a limited amount of geophysical data to verify the dip of targeted faults for drilling projects. Currently, an MT survey for the Canby Project may cost between $50-$75,000 but may provide the additional data needed for a successful drilling project.

It is recommended that the final results from this project should be viewed in the context of an ongoing development of a geothermal resource. Every directed action and the lessons learned from them will ultimately yield beneficial long-term results for the Canby Community and California.

Another recommendation would be to recognize that cascaded geothermal systems can have large impacts while yielding relatively small resources. The fact that the existing geothermal district heating system in Canby uses only an average of 16 gpm to heat and provide domestic hot water for over 70,000 ft^2 of agricultural, residential, and commercial buildings is significant in an area where outside temperatures range from -20°-110°F over the course of a year.

This project has relevance with respect to the low productivity of the ISO-2 geothermal well in this report since the initial productivity of the well is expected to be approximately 80 gpm with a drawdown of approximately 250 ft.. Because of this, our recommendation would be to encourage Energy Commission staff to structure future contracts with contractors installing a cascaded system in such a way that would give them the ability to complete the project if revised plans for the resource can demonstrate long term viability.

GLOSSARY

BOPe	Blow Out Prevention Equipment
Canby Project	Canby Geothermal Development Project
Energy Commission	California Energy Commission
CEQA	California Environmental Quality Act
°	Degrees
F	Fahrenheit
ft.	Feet
gpm	gallons per minute
GRDA	Geothermal Resource Development Account
HR	Hydro Resources
Hydro	Hydro-Resources
in.	Inches
MCC	Modoc Contracting Company
MT	Magnetotelluric
NPDES	National Pollutant Discharge Elimination System
ppg	pounds per gallon
ROP	Rate of Penetration
TD	Total Depth
USDOE/DOE	United States Department of Energy
WOB	Weight on Bit

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LaFleur, J. and Michael Krahmer. 2011. *Final Drilling and Geological Report of the ISO-2 Geothermal Production Test Well at Canby, Modoc County, Northeast California.* California Energy Commission, GRDA Program. GEO-07-001

APPENDIX A:
Final ISO-2 Drilling and Geological Report

FINAL DRILLING AND GEOLOGICAL REPORT

OF THE

ISO-2 GEOTHERMAL PRODUCTION TEST WELL

AT CANBY, MODOC COUNTY,

NORTHEAST CALIFORNIA

Prepared for Dale Merrick

Canby Cascaded Geothermal Development Project

Modoc Contracting Company, Inc.

by

Joe LaFleur and Mike Krahmer

Geologist Extraordinaire & Associates, LLC

October 2011

SUMMARY

The surface portion of the ISO-2 Well was completed in the first week of March 2011. The hole was drilled to 1440 feet and 13.375 inch surface casing was successfully landed and cemented. The casing shoe was placed at a fortuitously competent formation at 1427 ft. depth. Description of this upper portion of the hole is provided in the attached report: LITHOLOGY OF THE PRODUCTION 13.375 INCH CASING SECTION OF THE CANBY GEOTHERMAL WELL ISO-2 MODOC COUNTY, CALIFORNIA. This top part of the well was drilled with a reverse circulation rig. A regular circulation rotary rig, that would accommodate blowout preventors, was brought in to complete the hole.

In September 2011, the ISO-2 exploration well was advanced by drilling a 12.25″ diameter production test interval from 1427′ to 3852′. The well experienced no loss circulation and cut a lithologic section that showed only weak hydrothermal imprint in places. At the 3852′ TD point of the well, a static pressure and temperature log and the electric logs of gamma, spontaneous potential (SP), and electrical resistivity were run to identify zones of possible permeability. The most pertinent zones of possible warm water entry identified by the wireline logs were at 2494′-2644′, 2846′-2960′, and at 3018′-3044′. Even though the drilling and wireline results were disappointing, the decision was made to run slotted liner because the clay-rich formation between 1427′ and 2050′ was unlikely to remain open over time. The 9.625″ liner shoe was hung at 3300′ and the 12.25″ section of hole from 3300′-3852′ was left uncased because more competent rock was encountered in that section of hole.

BACKGROUND

The geologic setting that was present during the deposition of the lithologic units at Canby basin was essentially one of volcanoes erupting in and around lakes and streams. This thick accumulation of subaerial and subaqueous deposition has been named the Alturas Formation. The volcanic rocks of the Alturas Formation are Tertiary in age, approximately 8 to 10 million years old. These igneous eruptions are too old to provide heat to the existing hydrothermal systems in the area. The local hydrothermal systems are "fault plays". Typical of the Basin and Range Province geothermal systems, they are the result of meteoric water descending deeply within fault zones where it becomes heated at depth by the regional thermal gradient and are not associated with a magmatic heat source.

The ash, cinders, lava flows, and various volcaniclastic rocks of the Alturas Formation were deposited both on the land surface and sometimes directly into the lakes. As the subaerial deposits were eroded, streams carried the resultant sand, gravels, and clays into the adjacent lakes. During drilling, the rocks are broken up into various sized fragments. Depending on the size of the drill cutting fragments, the grain size of the specific lithologies, and the degree of alteration, it may or may not be possible to distinguish between subaerial and subaqueous deposition. The lithologic logs attached attempt to make that determination to the best of our ability; however, this distinction is not as critical as is the recognition of the secondary minerals that are indicators of hydrothermal activity.

Drill cutting samples were collected at 10-foot intervals during the drilling of the ISO-2 Well. The cuttings were logged and described by use of a 10X to 60X zoom binocular microscope by professional mud loggers and by geothermal geologists Joe LaFleur and Mike Krahmer. Rock color was correlated to GSA rock color chart; carbonate content was checked with 10 percent HCl; magnetite was routinely checked for; and a steel probe was used to determine hardness. Descriptions of the well and drill cuttings are provided with this report.

LITHOLOGY

The section of rock cut in the 12.25" diameter hole section of the ISO-2 Well was a series of intercalated tuffs, debris flows, lava flows, and volcaniclastic sediments filling the Canby basin. Overall, the rock appeared to be mafic with composition probably made up of mostly basaltic andesite and trending to dacitic andesite in places. Two significant sequences of tuffaceous siltstone were encountered at 1780′-1820′ and 1870′-2050′ that were very argillaceous which resulted in plugging the drilling rig's pitcher nipple at times and created a problem with solids control in the drilling mud. The siltstone contained carbonaceous material in places but no hydrocarbon gases were recorded by Pason's total gas analyzer. Overall, some of the tuffs logged and described in the section from 1427′ to 2050′ could have a sedimentary component.

Below 2180′, a more competent volcanic series was encountered. It consisted of crystal tuffs, lithic tuffs, and basaltic lavas. A debris flow deposit was cut at 3190′-3270′ and it was decided at the completion of the well to make sure this stratigraphic bed was cased off for hole integrity. From 3360′ to 3850′ a series of basaltic andesite lavas and crystal tuff deposits were cut. Due to the hardness of the rock, the drill rate decreased significantly and to some extent was responsible for the decrease in the mud-out and mud-in temperatures that were noted for this section of the hole.

Secondary mineralization was sparse with only a weak imprint of smectite, celadonite, and calcium-zeolites occurring in minute to minor quantities in places. This mineral assemblage could be indicative of warm water (<125°C) being present in a conductive setting in volcanic rocks. In the bottom of the hole, below 3730′, it appeared that smectite was beginning to transition to chlorite. Veining was largely absent and indistinct in the few places that it was noted. Pyrite was mostly absent. Calcite occurrence was sparse, but was found in rare amounts in the debris flow deposit at 3190′ to 3270′. An unidentified white clay mineral, probably occurring as fracture coatings or cavity-fill, was noted in the basal basaltic andesite flows between 3360′ and 3630′. The most pervasive secondary mineral encountered below 2200′ was hematite and it is unclear whether the occurrence of that mineral is related to alteration occurring during emplacement or groundwater alteration of the rock.

DRILLING

Once drilling operations commenced, the 2425′ of 12.25″ hole was accomplished in 8 days. In the upper section from 1440′ to 2150′, clay clogging the flow line and plugging of the shakers was a problem that limited progress at times. The project drilling supervisor reported swelling clays encountered from 1535′ to 1735′ and they tripped out of the hole to treat the mud and raise its weight from 8.7 ppg to 9.3 ppg. Increasing solids in the mud resulted in the mud-weight going from 9.3 ppg to a 9.6 ppg at the bottom of hole despite periodic dumping of the sand trap. Despite the higher mud-weight, no loss circulation was observed at any time during the drilling of this hole. Hole deviation was kept below 3° up to 3118′. The survey at 3407′ was 7° as a result of increased WOB (weight on bit) and perhaps some contribution by the formation. WOB was reduced, and coupled with the increased hardness of the basaltic andesite at the bottom of the hole, the ROP (rate of penetration) was significantly lower for the interval between 3450′ and 3852′ TD. The final deviation survey at 3812′ was 2° off vertical.

Because the mud-out temperature was not demonstrating encouraging gain (and in fact had cooled off a few degrees) and no encouragement was observed in the cuttings, a decision was made to quit drilling. At that time the well was at a depth of 3852′.

COMPLETION

The well was completed in such a manner as to:

1. Leave the hole in such a way that it can be re-entered and deepened or hydro-fractured if desired. The 9.625" (40 lb/ft.) liner was hung inside the 13.375" casing and not cemented so as to be removable if necessary.
2. Preserve potentially permeable zones as suggested on the geophysical logs by placing slotted liner over those intervals.
3. The bottom of the 9.625″ liner is at 3,300′ because the lower 550′ of the hole appeared competent enough to remain open.
4. Allow for an injection test to be conducted to evaluate overall permeability of the hole.
5. Facilitate additional logging of the temperature profile of the well.

WIRELINE SURVEYS

The hole was logged 14.5 hours after circulation. The first suite of logs ran included pressure, temperature, and gamma ray tools. It was logged down at 100 ft./sec, with a 10-minute temperature build up on bottom, and logged back up at 30 feet/sec. The second logging run included spontaneous potential, electrical resistivity, and temperature. It was run from the bottom of the hole up to the shoe of the 13- 3/8" casing at a logging rate of at 50 ft./sec. The temperature log basically shows a gradual increase in temperature from the near surface almost to the bottom. At a depth of about 3600', the temperature profile became essentially isothermal at about 170° F, which continued down to the total depth of 3852′. There is indication on the log that the hole was actually starting to cool a degree or two in the last 100′ from bottom.

The initial temperature log taken immediately after the completion of drilling a well is often a disturbed temperature profile because the hole has not had adequate time to thermally equilibrate; however, it can provide insight into the location of permeability within the well bore. Often zones of permeability will be cooled due to drilling fluids migrating into the hydrothermal pathways and sweeping heat out of the well bore in those areas. In ISO-2, the most pronounced reversals occur at 2534′-2617′ and 3780′-3852′. Other slight inflections on the temperature logs are noted around the areas of 3030′ and 3380′.

SP and resistivity measure the amount of fluid invasion into the well bore and are often used to infer permeability within the well profile. The SP shows little variation and the difference between the shallow and deep resistivity is nil between 1427′ and 2150′. This confirms the observation in the drill cuttings that indicated a very impermeable section of the hole, probably due to the argillaceous nature of the rocks in that section.

With regard to zones that might be permeable as indicated by the SP and resistivity measurements, the zone between 2494′-2644′ stands out and contains the noted temperature reversal in the area of 2534′-2617′. The rocks in this section are basaltic crystal lithic tuff with abundant to common hematite and rare to minor smectite. Possible slickensides were noted in the 2570′ and 2580′ samples.

Other zones of possible permeability indicated by the electric logs are 2846′-2960′ (which is a zone of andesite crystal lithic tuffs with a secondary mineral assemblage of smectite + zeolites + hematite ± calcite), and the zone at 3018′-3044′, which matches a temperature inflection at 3030′. The rest of the bright spots on the SP and resistivity logs, in order of a subjective ranking of interest are: 3770′-3806′, 3266′-3276′, 3360′-3380′, and 2234′-2270′.

The Gamma log showed fair correlation with the lithologic log and delineates and confirms some of the mafic lavas and crystal tuffs noted in the rock descriptions.

DISCUSSION

The result of the well was that it did not identify a higher temperature resource at depth. The cuttings did not contain secondary mineralization typical of hydrothermal systems, past or present. The temperature of the hole, as suggested by recorded mud-in versus mud-out temperature variations, did reflect the shallower resource zone as was encountered in the ISO-1 well, but it did not offer encouragement for a higher temperature resource at depth.

It is noteworthy that the shallow resource zone was reflected in the mud-out temperature record, but not in the temperature logging conducted at the end of drilling. We anticipate that this zone will show up in subsequent logging of the well.

The initial temperature log that is taken at the end of drilling is not reliably accurate because the hole has not had adequate time to thermally equilibrate; however, it might be indicative of an important insight in this case. The fact that the bottom 250′ of the ISO-2 Well appears to be isothermal may be significant. It might argue that there is not a higher temperature hydrothermal system close beneath the well bore. Cold-water hydraulic masking would probably not be a factor in this geo-hydrologic setting. The masking of heat flow by relatively deep meteoric cool water aquifers occurs locally in settings like the Cascade Range. There, the high recharge head from the tall volcanoes can feed deep, sloping aquifers beneath their flanks.

The ISO wells are drilled into a fairly small basin with a relatively limited recharge head. At the depth of almost 4,000 ft., it is unlikely that there are horizontally moving groundwater aquifers to mask the heat-flow from below.

The high plateaus that border Canby basin do not constitute strong recharge potential for deep aquifers because they do not constitute high relief like the Cascade volcanoes or the large horst blocks typical of the Basin and Range Province. And, although the surrounding plateaus are capped with fractured lava flows, those flows are underlain by impermeable lake beds, ash layers, and clay-rich tuffaceous deposits that preclude passageway for meteoric water to feed moving aquifers at depth. That is why the plateaus have numerous springs issuing from their bases and from beneath the basalt cap-rock lava flows.

The measured bottom hole temperature of 170° F may show some increase with time. Some holes take weeks, even months to fully thermally equilibrate and the ultimate temperature profile often appears quite different from the initial temperature log. However, 170° F at about 4,000 feet is what would be anticipated from just regional gradient. If one assumes a regional gradient of 3° F/ 100 ft. and an initial surface temperature of 50°F, it calculates out to 170° F at 4,000 ft. depth.

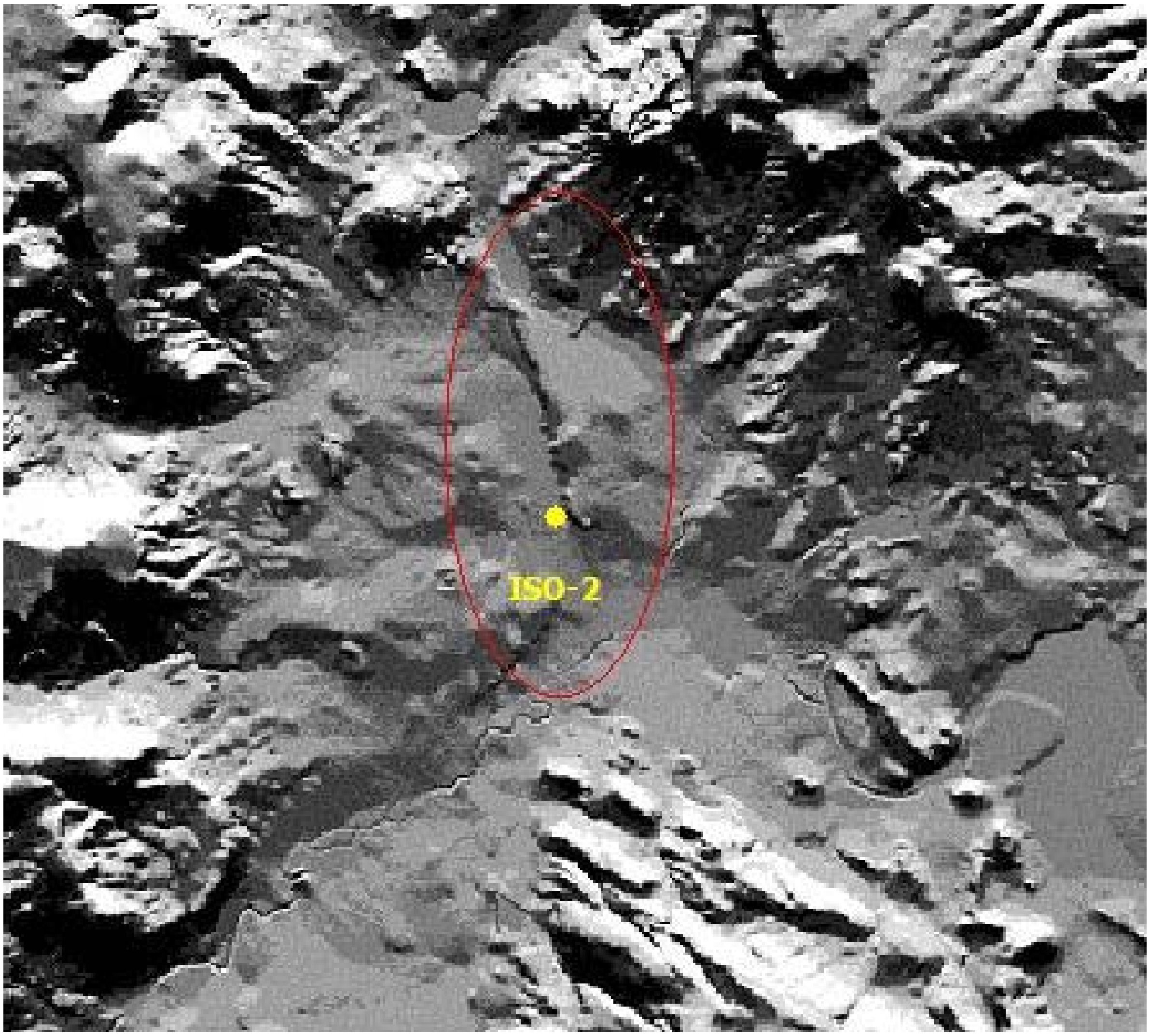
A recent and easily identified fault, interpreted to be dipping beneath the ISO-2 drill site, was selected as the target fault. Although the trace of the fault is easily mapped (see below), the true dip of the fault is unknown and was assumed to be typical of average Basin and Range Province faulting. Whether the target fault was intersected or not is unknown, but we are skeptical that it was. There was nothing in the cuttings that suggested fault gouge and there were no lost circulation zones experienced in the well. It is possible that the fault was intersected at a place where the lithology was too incompetent to support open fracturing that would help identify the fault. But perhaps it is more likely that the targeted fault dips too steeply to have been intersected by the 3,852 ft. deep well. If the fault dips more steeply than about 67 degrees, it would not have been intersected by the ISO-2 Well. Some Basin and Range faulting has been found to be near-vertical. Regardless of whether or not the target fault was actually encountered, it does not appear to be a major conduit for higher temperature hydrothermal fluids. There was nothing in the cuttings or temperature log that suggests an "upflow fault" is close at hand.

RECOMMENDATIONS:

1. Conduct detailed temperature logging of the well after it has had adequate time to thermally equilibrate.
2. Log the well at different times in the forthcoming year.
3. At some point, run a pump test.
4. Use a down-hole sample catcher to see if there is variation in the fluid chemistry with depth.

1 Attachment as stated (the lithologic description of the surface hole, 0 to 1440 ft.)

The NNW-Trending Target Fault on Satellite Radar Imagery



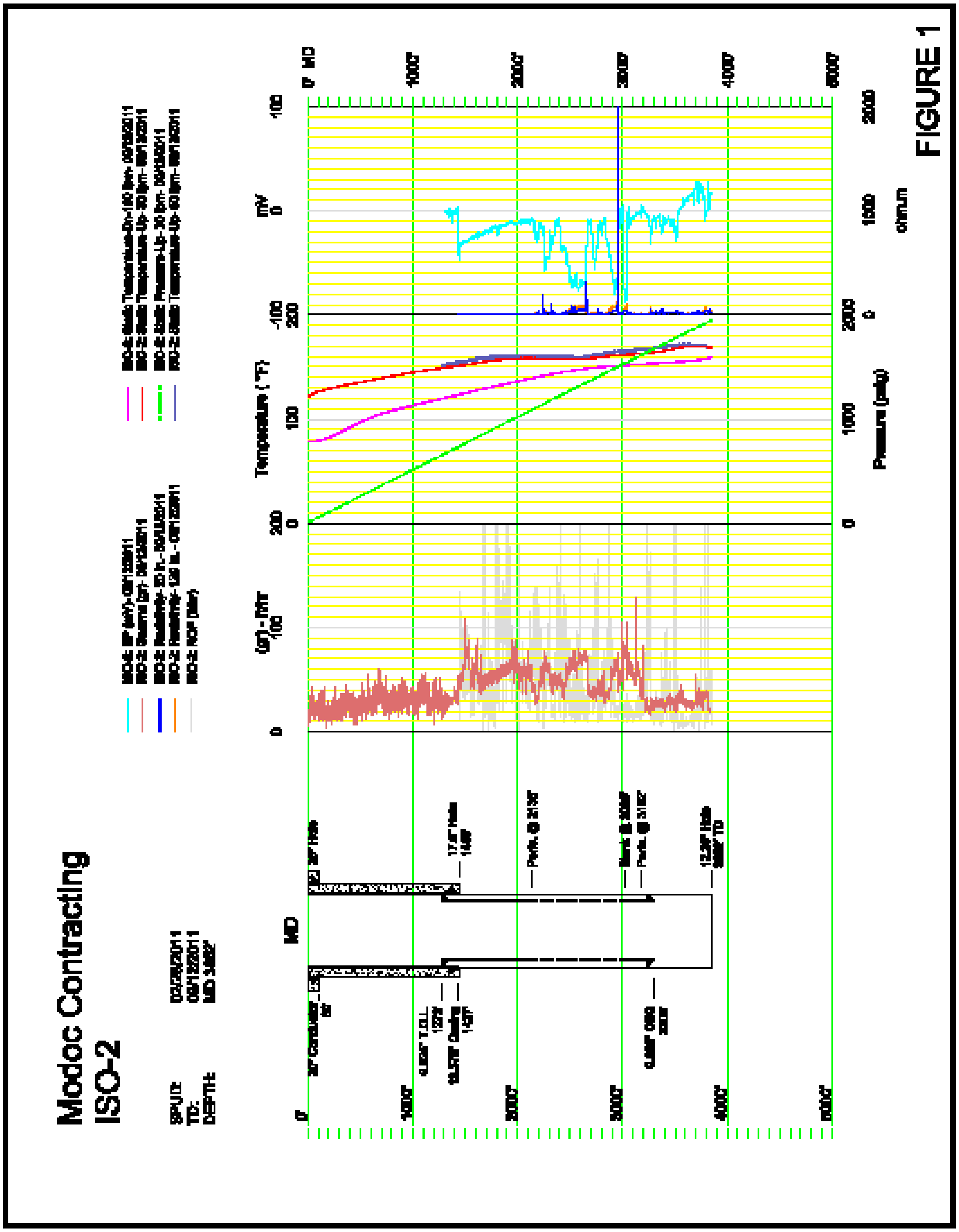
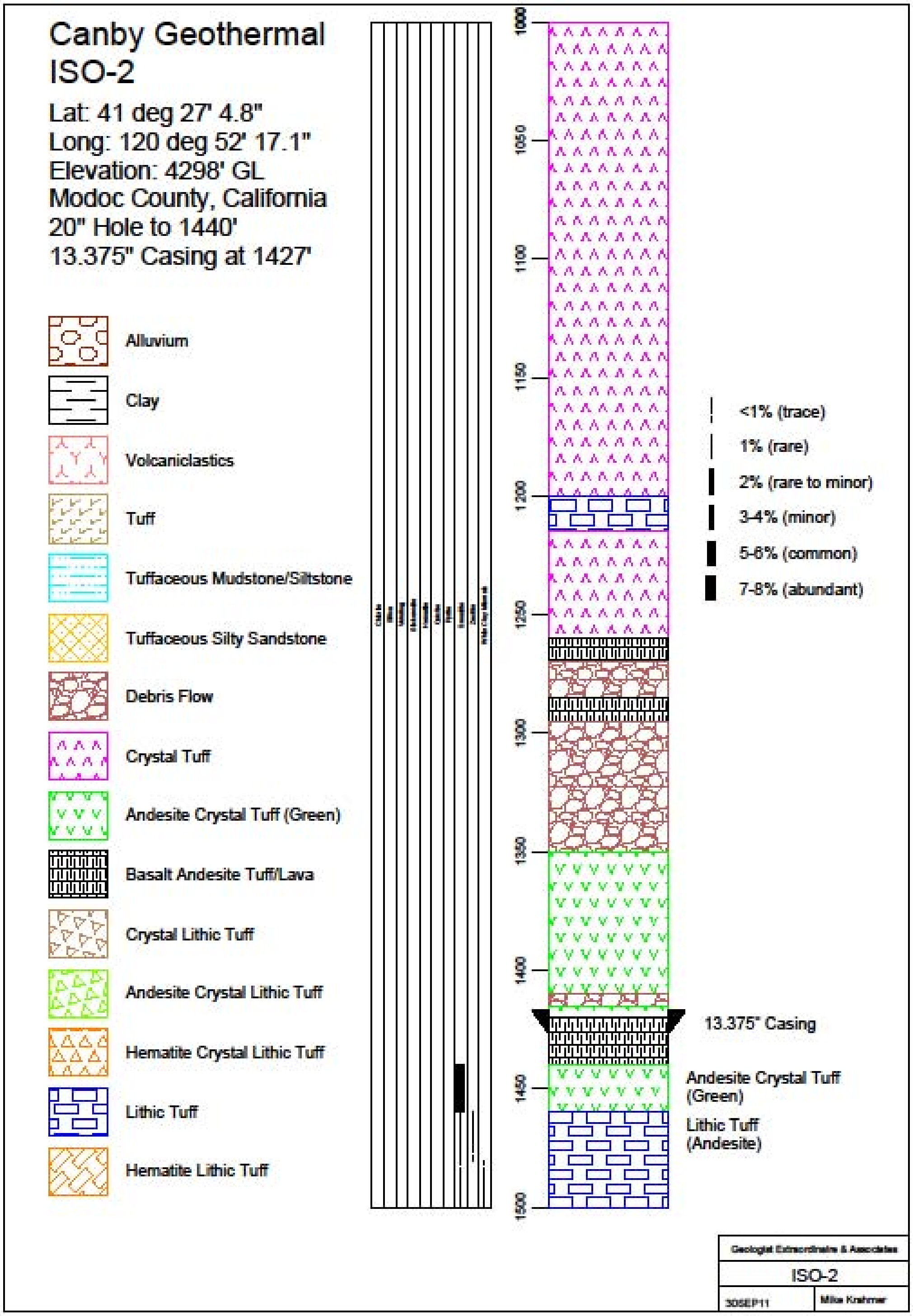
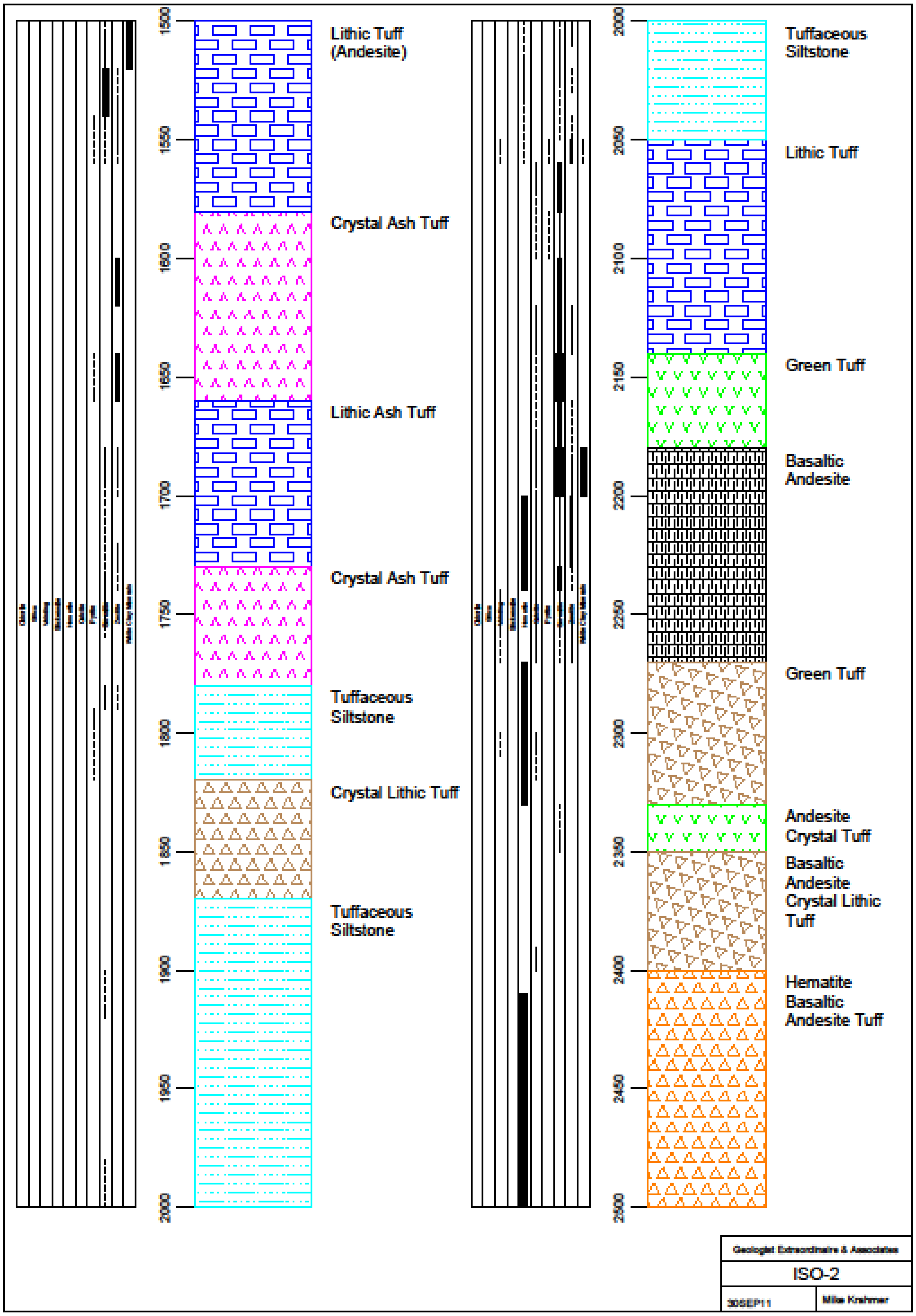
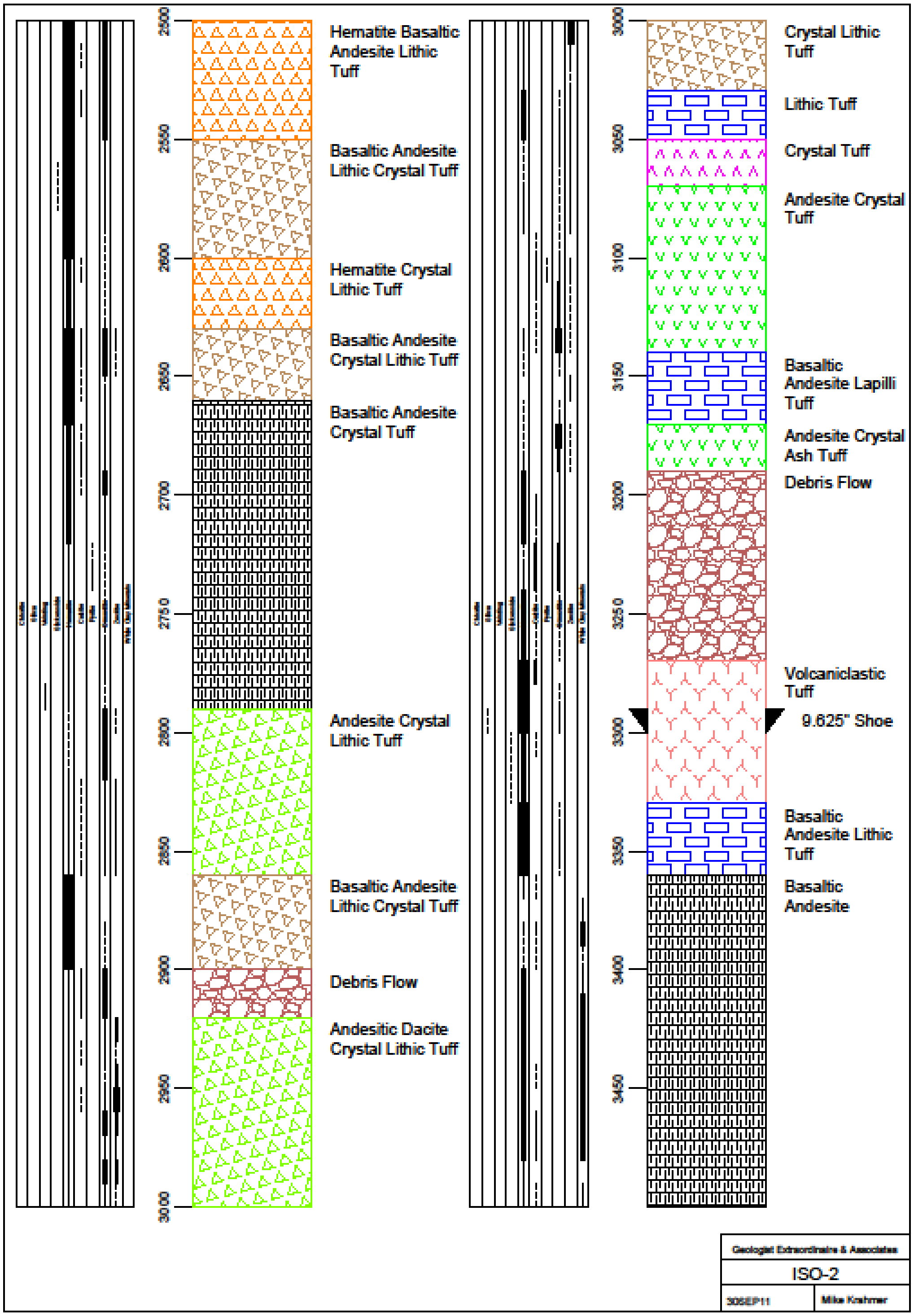

Modoc Contracting
ISO-2
MD
Temperature (°F)
Pressure (psia)
ohm.m
mV
0' MD
1000'
2000'
3000'
4000'
5000'

FIGURE 1

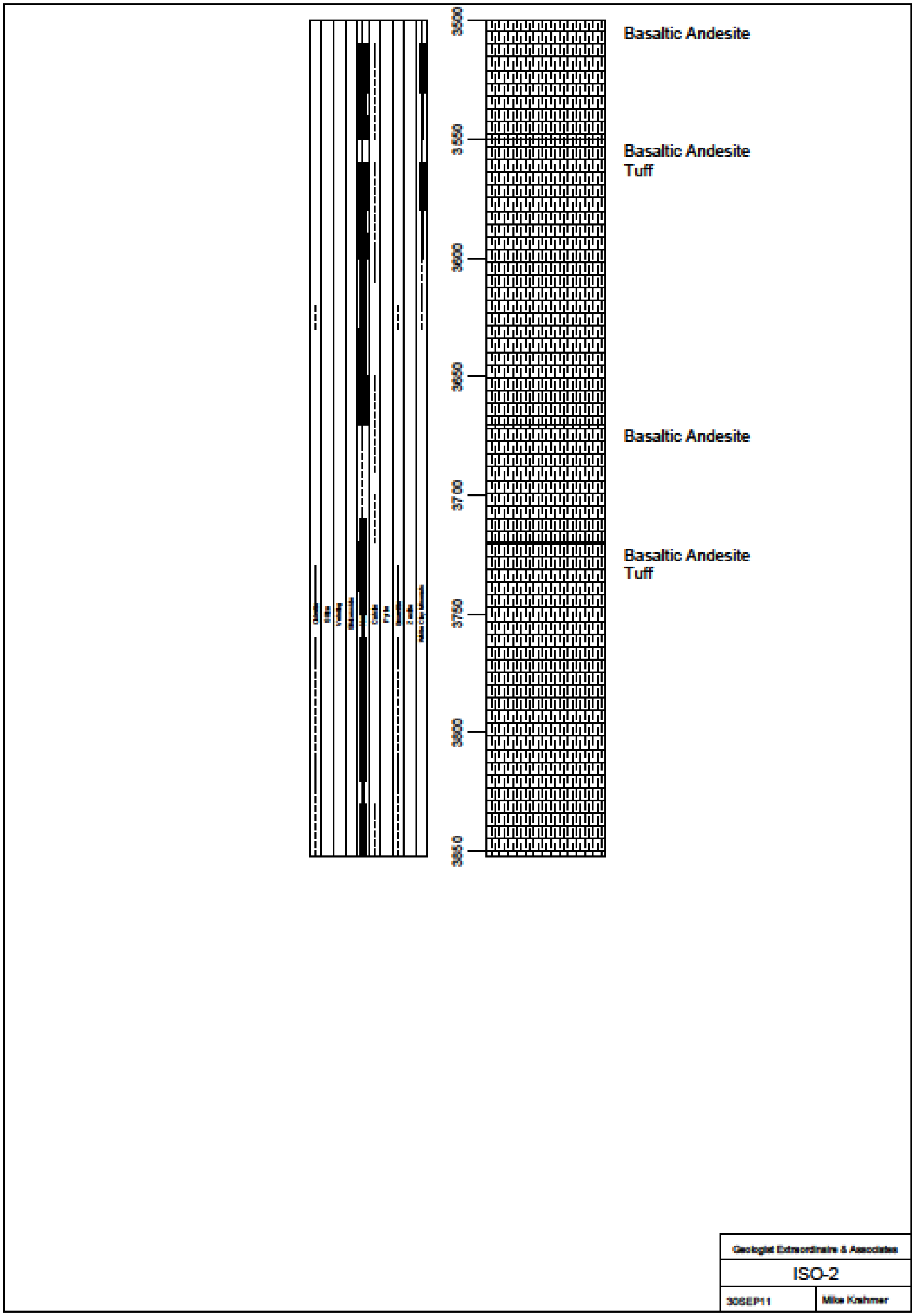


Canby Geothermal
ISO-2
Lat: 41 deg 27' 4.8"
Long: 120 deg 52' 17.1"
Elevation: 4298' GL
Modoc County, California
20" Hole to 1440'
13.375" Casing at 1427'
Alluvium
Clay
Volcaniclastics
Tuff
Tuffaceous Mudstone/Siltstone
Tuffaceous Silty Sandstone
Debris Flow
Crystal Tuff
Andesite Crystal Tuff (Green)
Basalt Andesite Tuff/Lava
Crystal Lithic Tuff
Andesite Crystal Lithic Tuff
Hematite Crystal Lithic Tuff
Lithic Tuff
Hematite Lithic Tuff
1000
1050
1100
1150
1200
1250
1300
1350
1400
1450
1500
<1% (trace)
1% (rare)
2% (rare to minor)
3-4% (minor)
5-6% (common)
7-8% (abundant)
13.375" Casing
Andesite Crystal Tuff (Green)
Lithic Tuff (Andesite)
ISO-2
30SEP11
Mike Krahmer


1500
1550
1600
1650
1700
1750
1800
1850
1900
1950
2000
Lithic Tuff (Andesite)
Crystal Ash Tuff
Lithic Ash Tuff
Crystal Ash Tuff
Tuffaceous Siltstone
Crystal Lithic Tuff
Tuffaceous Siltstone
2000
2050
2100
2150
2200
2250
2300
2350
2400
2450
2500
Tuffaceous Siltstone
Lithic Tuff
Green Tuff
Basaltic Andesite
Green Tuff
Andesite Crystal Tuff
Basaltic Andesite Crystal Lithic Tuff
Hematite Basaltic Andesite Tuff
ISO-2
30SEP11
Mike Krahmer



2500
2550
2600
2650
2700
2750
2800
2850
2900
2950
3000
Hematite Basaltic Andesite Lithic Tuff
Basaltic Andesite Lithic Crystal Tuff
Hematite Crystal Lithic Tuff
Basaltic Andesite Crystal Lithic Tuff
Basaltic Andesite Crystal Tuff
Andesite Crystal Lithic Tuff
Basaltic Andesite Lithic Crystal Tuff
Debris Flow
Andesitic Dacite Crystal Lithic Tuff
3000
3050
3100
3150
3200
3250
3300
3350
3400
3450
Crystal Lithic Tuff
Lithic Tuff
Crystal Tuff
Andesite Crystal Tuff
Basaltic Andesite Lapilli Tuff
Andesite Crystal Ash Tuff
Debris Flow
Volcaniclastic Tuff
9.625" Shoe
Basaltic Andesite Lithic Tuff
Basaltic Andesite
Geologist Extraordinaire & Associates
ISO-2
30SEP11
Mike Krahmer


3500
3550
3600
3650
3700
3750
3800
3850
Basaltic Andesite
Basaltic Andesite
Tuff
Basaltic Andesite
Basaltic Andesite
Tuff
Geologist Extraordinaire & Associates
ISO-2
30SEP11
Mike Krahmer

LITHOLOGIC NOTES

1420′-1440′ CRYSTAL ASH TUFF: Very light gray to white; moderately hard; fragmental texture; ash matrix devitrified to silica and clay minerals; common to abundant micro-spherical fragments with coating of clay minerals on inner and outer rims; loc abundant loose subhedral quartz and plagioclase; local Basaltic Andesite fragments.

1440′-1460′ ANDESITIC CRYSTAL LITHIC TUFF / GREEN TUFF: Grayish green; multicolored under scope; fragmental texture with common grayish Andesite fragments intermixed with smectite altered fragments.

1460′-1480′ CRYSTAL LITHIC TUFF: Light gray; moderately hard to soft; fragmental texture; common loose plagioclase phenocrysts; trace to rare smectite altered fragments; trace clear six sided euhedral zeolite.

1480′-1500′ ANDESITE LITHIC TUFF: Dark medium gray overall; moderately hard; fragmental texture with common rounded Andesitic fragments; trace white mineral coating on some vesicles fragments; trace smectite.

1500′-1520′ LITHIC TUFF: Grayish green; moderately hard; fragmental texture commonly cemented with white clay mineral; trace smectite; minor white clay mineral.

1520′-1540′ LITHIC TUFF: Generally as above; trace scoriaceous fragments; trace zeolite; minor smectite.

1540′-1560′ ANDESITE CRYSTAL LITHIC TUFF: Medium gray; moderately hard to soft; fragmental texture with multicolored grains under scope; trace smectite; trace zeolite; trace pyrite.

1560′-1580′ LITHIC TUFF

1580′-1600′ ASH TUFF

1600′-1620′ CRYSTAL ASH TUFF: Light olive gray; moderately hard; brittle; crypto-crystalline to micro-crystalline; very siliceous; rare to minor clear euhedral crystals – probably zeolites.

1620′-1640′ ASH TUFF: Light gray; moderately hard; brittle; cryptocrystalline; devitrified matrix altered to clay minerals and siliceous material.

1640′-1660′ ASH TUFF: Generally as above; trace subhedral pyrite; rare to minor clear zeolites.

1660′-1680′ LITHIC ASH TUFF: Medium gray overall; multicolored under scope with mix of leucocratic and mafic fragments; trace euhedral biotite.

1680′-1700′ LITHIC ASH TUFF: Generally as above; trace zeolite; trace smectite; trace mottled texture; rare fiamme.

1700′-1710′ ANDESITE LITHIC ASH TUFF: Medium gray overall; white to yellowish gray under scope with some dark gray fragments; mushy to soft to moderately hard; fragmental texture with abundant subrounded to rounded fragment; white fragments are crypto-crystalline and appears to be a mix of devitrified clay and silica; gray fragments are aphanitic Andesite; clay mineral matrix is pulverized to sticky soluble clay made by bit action; trace of smectite; rare blue gray clay mineral coating some fragment faces; trace scoriaceous fragments; slight trace warm water alteration.

1710′-1720′ ANDESITE CRYSTAL LITHIC TUFF: Medium dark gray; moderately hard to friable; blocky and irregular cutting habit; olive gray fragments are Ash Tuff; dark gray grains are Basaltic Andesite; minor loose clear anhedral crystals; rare smectite; trace blue gray clay mineral coating on selected fragments; very slight trace of euhedral pyroxene crystals.

1720′-1730′ ANDESITE CRYSTAL LITHIC TUFF: Generally as above; rare orthogonal zeolites; trace smectite; continued slight warm water alteration.

1730′-1740′ CRYSTAL ASH TUFF: Yellowish gray overall; moderately hard to friable; clay will pulverize to sticky clay by bit action if fluid loss is not tracked; crypto-crystalline to micro-crystalline; rare black brown ribbon-like laminae in one fragment; trace smectite; trace orthogonal zeolite; trace scoriaceous fragments.

1740′-1750′ CRYSTAL ASH TUFF: Generally as above with abundant loose quartz + plagioclase grains in tray; trace smectite and blue gray clay mineral coating some grains; very slight warm water alteration.

1750′-1760′ CRYSTAL ASH TUFF: Medium light gray overall; some white and olive gray fragments; friable to soft; siliceous and argillaceous; minor to common clear crystal shards loose in the tray; trace smectite; rare fragments with ribbon-like micro-laminae of brownish black material possibly biotite or carbonaceous material.

1760′-1770′ CRYSTAL ASH TUFF: Generally as above with rare smectite; slight increase in cryptocrystalline olive gray material with flat to splintery fracture, and argillaceous matrix material.

1770′-1780′ 90 PERCENT NUT PLUG/GROUND WALNUT SHELLS AND 10 PERCENT CRYSTAL ASH TUFF: Generally as above.

1780′-1790′ TUFFACEOUS SILTSTONE: Medium dark gray; moderately hard to friable; some flat and splintery shale-like fracture but mostly blocky and irregular cutting habit with subrounded to subangular edges; smectite; trace clear crystal shard which is possibly zeolite.

1795′: POOH for bit check @ 18:30 hr. Change out bit, drop stabilizers, and condition mud. Bring up MW, Vis, lower gel strength, lower filtrate; and increase alkalinity.

1790′-1820′ TUFFACEOUS SILTSTONE: Medium gray overall; moderately hard and friable; fragmental texture; probably water-lain, but possibly a Lithic Tuff; abundant clear subhedral plagioclase found loose in tray; trace pyrite.

1820′-1840′ CRYSTAL LITHIC TUFF: Light olive gray to medium gray; moderately hard to friable; fragmental texture; felsic to siliceous; abundant clear euhedral plagioclase and quartz grains in matrix found loose in the tray.

1840′-1870′ CRYSTAL LITHIC TUFF: Light olive gray; friable to soft; loose and unconsolidated; argillaceous and siliceous; minor biotite.

1870′-1900′ **TUFFACEOUS SILTSTONE:** Grayish olive; soft to friable; fragmental texture; loose, blocky fragments with high sphericity; minor biotite; trace brick red scoriaceous fragments.

1900′-1920′ **TUFFACEOUS SILTSTONE:** Grayish olive; mix of silt and clay composed fragments; trace smectite; abundant Claystone fragments with well-rounded edges.

1920′-1960′ **70 PERCENT TUFFACEOUS SILTSTONE / 30 PERCENT CRYSTAL LITHIC TUFF:** Medium gray overall; fragments can be light olive gray, clear, white, and other hues; olive gray fragments are massive and micro-crystalline and soft and appear to grade from Mudstone to Siltstone; white to light gray fragments are siliceous to felsic and appear to be mostly composed of Ash Tuff; clear grains are crystal shards; overall composition of rock probably falls between Andesite to Dacite; possible brownish black carbonaceous material in sedimentary fragments; slight low temperature argillic hydrothermal alteration imprint.

1960′-1980′ **70 PERCENT TUFFACEOUS SILTSTONE / 30 PERCENT CRYSTAL LITHIC TUFF:** Generally as above; more loose crystal shards; minor carbonaceous material – checked with mudman – adding no lignite or other black material.

1980′-2000′ **70 PERCENT TUFFACEOUS SILTSTONE / 30 PERCENT CRYSTAL LITHIC TUFF:** Generally as above; rare scoriaceous moderate brown fragments; trace smectite.

2000′-2050′ **70 PERCENT TUFFACEOUS SILTSTONE / 30 PERCENT CRYSTAL LITHIC TUFF:** Medium dark gray overall; individual fragments are olive gray, clear, moderately brown, or pale green; friable; argillaceous; appears to be water lain as evidenced by the shale-like appearance of a majority of fragments and some laminae and chunks of carbonaceous material; crystal shards vary from anhedral to euhedral and are probably a mix of plagioclase, zeolite, or quartz; trace smectite; trace hematite altered tuff fragments.

2050′-2060′ **LITHIC TUFF:** Dark gray overall; somewhat multicolored under scope; friable to soft with high clay content overall fragments in order of abundance of occurrence: Pale yellowish brown silty Tuff fragments that are commonly micro-flecked with brown black carbonaceous material; medium bluish gray cuttings are massive clayey Tuff fragments with subround to rounded cutting edges; 4 percent moderate brown Tuff fragments with platy cutting habit; 2 percent to 4 percent clear to translucent crystal shards of plagioclase, zeolite, or quartz; slight hydrothermal overprint with one lone fragments of secondary pyrite as veining or amygdale-filling clustered about a lone unidentified euhedral crystal; trace smectite.

2060′-2080′ **LITHIC TUFF:** Generally as above; rare to minor smectite; trace pinpoint calcite.

2080′-2100′ **LITHIC TUFF:** Generally as above; rare smectite; trace pyrite.

2100′-2120′ **LITHIC TUFF:** A mix of grayish green smectite altered Tuff fragments and moderate brown massive Tuff fragments; common to abundant olive gray fragments that appear to have an affinity to smectite.

2120′-2140′ **LITHIC TUFF:** Multicolored; dark yellowish brown massive Tuff fragments; greenish gray to white smectite altered Tuff fragments; minor to common clear crystal shards some of which are zeolites; trace calcite.

2140′-2160′ **GREEN TUFF:** Mostly grayish green mottled with 10 percent grayish red brown fragments; probably an Andesite Crystal Lithic Tuff; altered to abundant smectite in places; trace calcite.

2160′-2180′ **50 percent GREEN TUFF / 50 percent LITHIC TUFF:** Green Tuff as above; moderate brown to dusky brown Lithic Tuff that is hematite altered; minor smectite; trace calcite; minor clear crystal shards.

2180′-2200′ **BASALTIC ANDESITE TUFF:** Dark gray to grayish black; hard and brittle and tough; aphanitic to porphyritic with portions of lithology showing mottled fragmented texture; common smectite and white clay mineral alteration; trace calcite; trace zeolites.

2200′-2230′ **BASALTIC ANDESITE:** Dark gray mottled with dark greens; smectite clays (celadonite to nontronite clays) as amygdale fill and lithic clast replacements; rare to minor monoclinic to orthogonal zeolite; rare calcite as fracture and amygdule-fill; minor to common brick red hematite altered tuff fragments that perhaps indicated baked flow top conditions.

2230′-2240′ **BASALTIC ANDESITE TUFF:** Grayish black, hard, fragmental texture; minor red Tuff fragments as/above; rare calcite; minor smectite; trace zeolite.

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2240′-2250′ **BASALTIC ANDESITE:** Grayish black; hard and brittle; blocky and irregular fracture; mostly aphanitic groundmass with bulk of the rock unaltered; trace smectite as amygdale-fill; rare calcite as fracture-fill.

2250′-2270′ **BASALTIC ANDESITE TUFF:** Medium dark gray; hard and brittle; aphanitic to fragmental texture; minor lithic fragments well fused into rock; trace plagioclase phenocrysts; trace smectite clays; trace 2 mm thick drusy mosaic crystals as amygdale-lining or vein material; crystals are probably zeolites and silica; trace calcite.

2270′-2330′ **BASALTIC ANDESITE CRYSTAL LITHIC TUFF:** Medium dark gray; moderately hard; ashy matrix well fused; minor entrained lithic fragments with very slight welding into matrix; trace plagioclase phenocrysts; mostly fresh and unaltered; trace pinpoint calcite; ashy matrix devitrified to clay minerals; minor Fe-oxides (limonite- hematite) altered lithic fragments perhaps indicative of a flow top or base; fracture-fill calcite at 2310′; trace pinpoint calcite at 2320′.

2330′-2350′ **ANDESITE CRYSTAL TUFF:** Greenish gray to grayish green; hard and brittle; micro-porphyritic with common lithic fragments entrained in matrix; no water and rock secondary minerals notes; slight green (smectite derived) cast on rock matrix.

2350′-2410′ **BASALTIC ANDESITE CRYSTAL LITHIC TUFF:** Medium gray; hard and brittle; somewhat porphyritic with abundant granular cuttings; appears unaltered with regards to secondary mineral alteration; ash matrix devitrified to clay in places; trace calcite at 2400′.

2410′-2420′ **HEMATITE BASALTIC ANDESITE TUFF:** Dusky red; lapilli-sized fragments which are moderately hard and brittle; overall rock is crumbly and poorly indurated (fused) or welded together; no alteration besides complete hematitic oxidation of the rock matrix.

2420′-2440′ **HEMATITE BASALTIC ANDESITE TUFF:** Moderately reddish brown; overall rocks is generally as above with even more visually vivid hematitic alteration of groundmass; some large plagioclase phenocrysts; no significant secondary mineral alteration noted.

2460′-2500′ **HEMATITE BASALTIC ANDESITE TUFF:** Mottled with dusky red to moderate brown; individual fragments are moderately hard to tough; rock is somewhat crumbly and friable due to fragmental texture; hematite or Fe oxidization is probably immediate post depositional/emplacement as remaining H2O entrained in volcanic rock flow steamed away during cooling; no obvious secondary water-rock-gas low temperature hydrothermal minerals noted.

2500′-2510′ **HEMATITE BASALTIC ANDESITE LITHIC TUFF:** Multicolored; 65 percent moderate red; 35 percent greenish gray; moderately red hued fragments are extensively oxidized by hematite throughout groundmass and are commonly welded or scoriaceous in places; often massive; cutting containing lithic fragments are matrix supported; rarely rock is porphyritic; greenish gray fragments are somewhat washed through with smectite clays; hematite=6 percent; smectite=2 percent; calcite=none.

2510′-2520′ **HEMATITE BASALTIC ANDESITE LITHIC TUFF:** Generally as above; trace yellow Fe2O3 mineral; hematite=5 percent; smectite=2 percent; calcite=trace.

2520′-2530′ **HEMATITE BASALTIC ANDESITE LITHIC TUFF:** Generally as above; trace dark green celadonite mm thick coatings on gray Andesite fracture faces; hematite=5 percent; smectite=2 percent; calcite=none; possible trace of incipient pyrite or zeolite on one particular Andesite fragment face.

2530′-2540′ **HEMATITE BASALTIC ANDESITE LITHIC TUFF:** A mix of grayish red and dusky red fragments with the ash matrix devitrified to hematite + silica + clay minerals intermixed with 15 percent greenish gray Andesite clasts (?) showing moderate alteration to smectite clay probably between celadonite and nontronite; hematite=7 percent; smectite=2 percent; calcite=trace.

2540′-2550′ **HEMATITE BASALTIC ANDESITE LITHIC TUFF:** Generally as above; moderately welded in places with minor phenocrysts; hematite=8 percent; smectite=2 percent; calcite= none.

2550′-2560′ **BASALTIC ANDESITE LITHIC CRYSTAL TUFF:** Rock is predominately grayish red with 15 percent greenish gray cutting fragments; pervasive hematitic alteration is probably Basaltic Andesite matrix Fe-material being oxidized post depositional; greenish gray cutting are Andesite lithic clasts that are commonly altered to smectite clays; Tuff shows vitric welding in places; porphyritic with common euhedral plagioclase crystals; minor scoriaceous fragments with plagioclase phenocrysts occurring within the vesicles; hematite=7 percent; smectite=1 percent; calcite=none.

2560′-2570′ **BASALTIC ANDESITE LITHIC CRYSTAL TUFF:** Generally as above; possible slickensides – possibly from bit; hematite=6 percent; smectite=1 percent; and calcite=none.

2570′-2580′ **BASALTIC ANDESITE LITHIC CRYSTAL TUFF:** Generally as above; possible fault gouge in sample; hematite=5 percent; smectite=trace; calcite=none.

2580′-2590′ **BASALTIC ANDESITE LITHIC CRYSTAL TUFF:** Generally as above; hematite=5 percent; smectite=trace; calcite=none.

2590′-2600′ **CRYSTAL LITHIC TUFF:** Generally as above; matrix is well indurated and devitrified ash; hematite=5 percent; smectite=trace; calcite=trace.

2600′-2630′ **HEMATITE CRYSTAL LITHIC TUFF:** Generally as above; devitrified with some minor welded textures; minor phenocrysts mostly of euhedral to subhedral plagioclase; hematite=4 percent; smectite=trace; calcite was at trace at 2610′ and absent from 2620′ and 2630′.

2630′-2650′ **BASALTIC ANDESITE CRYSTAL LITHIC TUFF:** Various hues of moderate red with minor amounts of olive gray; white; dark gray and greenish gray fragments; rock matrix is oxidized to hematite; porphyritic with common plagioclase phenocrysts; no obvious secondary hydrothermal minerals noted; hematite=6 percent; smectite=2 percent; calcite = trace as pinpoint occurrence; zeolite=traces.

2650′-2660′ **BASALTIC ANDESITE CRYSTAL TUFF:** Generally as above; porphyritic with common medium sized crystal of euhedral plagioclase; no obvious veining or secondary minerals noted; hematite=7 percent; smectite=trace; calcite=trace.

LITHOLOGY COLOR CHANGE

2660′-2670′ **BASALTIC ANDESITE CRYSTAL TUFF:** 60 percent moderate red hues and 40 percent olive gray to grayish green; fragments are moderately hard and brittle; overall rock has a fragmental texture; tuff that possesses a hematitic matrix is commonly porphyritic; rare mafic sites replaced by moderate yellowish green smectite mineral; hematite=6 percent; smectite=trace; calcite=none.

2670′-2700′ **BASALTIC ANDESITE CRYSTAL TUFF:** 40 percent moderate red hues; 20 percent greenish gray hues; 30 percent pale yellowish brown hues; moderately hard and brittle; lava rock has a somewhat crumbly and fragmental texture; slightly porphyritic; common Crystal Ash Tuff fragments with 5 percent opaques; slight alteration of opaque minerals to smectite.

2680′: hematite=4 percent; smectite=1 percent calcite=trace

2690′: hematite=4 percent; smectite=1 percent calcite=1 percent

2680′: hematite=4 percent; smectite=2 percent calcite=trace

2700′-2720′ **BASALTIC ANDESITE CRYSTAL TUFF:** 80 percent dark gray cuttings; 10 percent red brown hued fragments and 10 percent olive gray to white cuttings; rock fragments are moderately hard with a fragmental texture; cutting habit is blocky to roughly spherical with subangular edges; aphanitic; lava to tuffaceous texture; mafic; abundant hematitic cuttings that are often scoriaceous occurring as lithic clasts; hematite=2 percent; smectite=trace; calcite=none.

2720′-2740′ **BASALTIC CRYSTAL TUFF:** Generally as above; more lava-like; aphanitic; trace celadonite material filling vesicles in places; hematite=1 percent; smectite=trace; calcite=none; pyrite=trace.

2740′-2760′ **BASALTIC ANDESITE CRYSTAL TUFF/LAVA:** Mostly dark gray with minor to common red hued hematitic stained fragments; hackly to irregular fracture; moderately hard and brittle; mostly aphanitic; hematite=1 percent; smectite=trace; calcite=none.

2760′-2770′ **BASALTIC ANDESITE TUFF:** Generally as above; hematite=1 percent; smectite=trace; calcite=none; trace magnetite.

2770′-2780′ **BASALTIC ANDESITE TUFF:** Generally as above; hematite=1 percent; smectite=trace; calcite=none; trace magnetite.

2780′-2790′ **BASALTIC ANDESITE TUFF:** Generally as above; hematite=1 percent; smectite=trace; calcite=none; zeolite=trace as fracture-fill clumps; trace magnetite.

LITHOLOGY CHANGE

2790′-2800′ **ANDESITE CRYSTAL LITHIC TUFF:** Medium dark gray to dark greenish gray; hard and brittle; aphanitic; some fracture-fill as clear to white subhedral crystalline material; hematite=trace; smectite=2 percent; calcite=none; trace magnetite.

2800′-2820′ **ANDESITE CRYSTAL LITHIC TUFF:** Generally as above; trace euhedral tabular zeolite; trace obsidian lithic fragments; hematite=trace; smectite=2 percent; calcite=none; trace magnetite.

2820′-2840′ **ANDESITE CRYSTAL LITHIC TUFF:** Generally as above; rare euhedral orthogonal to monoclinic zeolite (1 percent); rare smectite replacing nodules; hematite=1 percent; trace calcite; trace magnetite.

2840′-2860′ **ANDESITE CRYSTAL LITHIC TUFF:** Generally as above; rare euhedral orthogonal to monoclinic zeolite (1 percent); rare smectite replacing nodules; hematite=1 percent; trace calcite; trace magnetite.

2860′-2880′ **BASALTIC ANDESITE LITHIC CRYSTAL TUFF:** Moderate red hues with 20 percent gray hued cuttings; moderate hard; fragmental texture; massive to slightly welded to scoriaceous texture; prevalent hematite staining of lapilli sized clasts and cuttings; 7 percent hematite; trace limonite; no calcite; trace magnetite.

2880′-2900′ **BASALTIC ANDESITE LITHIC CRYSTAL TUFF:** Generally as above; trace obsidian fragments; rare euhedral pyroxene fragments; hematite=7 percent; smectite=trace; calcite=none; trace acicular hematite; trace magnetite.

2900′-2920′ **DEBRIS FLOW:** Dark greenish gray; moderately hard to hard grains; somewhat blocky equigranular cutting habit; slight cement or welding of fragments; minor euhedral pyroxene crystals; hematite=1 percent; smectite=2 percent; zeolite=trace; calcite=trace; trace magnetite.

2920′-2930′ **ANDESITE CRYSTAL LITHIC TUFF:** Brown gray; moderately hard; fragmental texture; devitrified ash matrix; with common hematitic alteration. This sample is significant because 1 percent-2 percent acicular rods of soft clear zeolites; hematite=1 percent; zeolite=2 percent; calcite=none; smectite=1 percent.

2930′-2940′ **ANDESITE CRYSTAL LITHIC TUFF:** Generally as above; possible trace of zeolite filled vein; hematite=1 percent; smectite=1 percent; zeolite=trace; calcite=trace.

2940′-2950′ **ANDESITIC DACITE CRYSTAL LITHIC TUFF:** Generally as above; primary composition assumed to be between Andesite and Dacite; hematite=1 percent; smectite=trace; zeolite=2; calcite=none.

2950′-2960′ **ANDESITIC DACITE CRYSTAL LITHIC TUFF:** Light brown; moderately hard; mottled and crude flow banding in place; somewhat porphyritic; does not appear to be water lain; minor amounts of white to clear, subhedral to euhedral zeolite of either monoclinic or orthogonal shape; hematite=1 percent; smectite=1 percent; zeolite=3 percent; calcite=trace.

2960′-2970′ **ANDESITIC DACITE LITHIC TUFF:** Generally as above; minor primary mafic mineral phase altered to light green smectite minerals; trace to rare nodular obsidian lithic clasts entrained in devitrified ash matrix; hematite=1 percent; smectite=3 percent; zeolite=2 percent; calcite=none.

2970′-2980′ **ANDESITIC DACITE LITHIC TUFF:** Generally as above with 1 percent obsidian clasts entrained in ash matrix devitrified to hematite + silica + clay minerals; hematite=1 percent; smectite=trace; zeolite=1 percent; calcite=none.

2980′-2990′ **ANDESITIC DACITE LITHIC TUFF:** Generally as above; with continued 1 percent obsidian; magnetite continues as a primary mineral phase; in this sample and through 3000′ the rock has a somewhat water lain appearance and may represent an erosional event; hematite=1 percent; smectite=2 percent; zeolite=2 percent; calcite=none.

2990′-3000′ **ANDESITIC DACITE LITHIC TUFF:** Generally as above; hematite=1 percent; smectite=1 percent; zeolite=trace; calcite=none.

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3000′-3010′ **CRYSTAL LITHIC TUFF:** Grayish red; moderately hard; brittle and crunchy; massive and mottled and somewhat flow banded; ash matrix devitrified to hematite + silica + clay minerals; trace hornblende phenocrysts; primary composition probably between Andesite and Dacite; no significant hydrothermal alteration besides minor acicular clumps of zeolites at 3010′; hematite=1 percent; smectite=none; zeolite=3 percent; calcite=none.

3010′-3020′ **CRYSTAL LITHIC TUFF:** Generally as above; hematite=1 percent; smectite=none; zeolite=1 percent; calcite=none.

3020′-3030′ **CRYSTAL LITHIC TUFF:** Generally as above; hematite=1 percent; smectite=none; zeolite=trace; calcite=none.

3030′-3050′ **LITHIC TUFF:** Multicolored; moderate reddish brown and 30 percent grayish green; moderate hard; brittle and crunchy; irregular cutting habit and fracture with angular to subangular edges; trace obsidian lithic clasts set in mostly basaltic Tuff fragments; no obvious hydrothermal alteration; hematite=2 percent; smectite=trace; zeolite=trace; calcite=none.

3050′-3070′ **CRYSTAL TUFF:** Somewhat multicolored; grayish red with 30 percent grayish green; moderately hard; brittle and crunchy; somewhat mottled; slightly welded in places; rarely scoriaceous; ash matrix mostly devitrified to clay minerals + silica + hematite; rare phenocrysts;

magnetite as an opaque mineral phase; alteration defined by zeolite clusters; rare zeolites; trace smectite; trace to rare deuteric hematite.

3070′-3090′ **CRYSTAL LITHIC TUFF:** Generally gradational from the Crystal Tuff; clay-rich ashy matrix; some meteoric derived Fe2O3 clay minerals; rare deuteric hematite; trace smectite; rare zeolite; no calcite noted.

3090′-3100′ **ANDESITE CRYSTAL TUFF:** Grayish yellow green; moderately hard; crumbly; porphyritic with slightly “salt and pepper” texture from 2 percent to 10 percent opaque mineral content in some fragments; cutting habit is equigranular; mafic phase dominated by pyroxene + hornblende+ magnetite; trace calcite; trace smectite.

3100′-3140′ **ANDESITE CRYSTAL TUFF:** Generally as above; grayish green to moderate green; lithology from 3090′ to 3140′ could be called a Green Tuff; somewhat vitric matrix strongly devitrified to clay minerals in places; porphyritic; smectite alteration is very vivid in places as for example the moderate green smectite wash in 3140′ sample; calcite as interstitial and pinpoint occurrence.

3100′-3110′: Calcite=trace; pyrite=trace; smectite=trace; zeolite=1 percent.

3110′-3120′: Calcite=trace; smectite=2 percent; zeolite=trace.

3120′-3130′: Calcite=trace-1 percent; smectite=2 percent; zeolite=trace.
3130′-3140′: Calcite=trace; smectite=3 percent; zeolite=trace; hematite=trace.

3140′-3170′ **BASALT ANDESITE LAPILLI TUFF:** Dusky brown; moderately hard; crumbly to brittle; mostly mafic lapilli sized equigranular mafic fragments sat in an ash matrix; trace loose crystal shards in 3160′ sample; no obvious hydrothermal alteration.

3140′-3150′ Hematite=trace; smectite=trace.

3150′-3160′ Zeolite=1 percent.

3160′-3170′ Hematite=trace; smectite=trace.

3170′-3190′ **ANDESITE CRYSTAL ASH TUFF:** “Green Tuff”; greenish gray; friable; commonly composed of equant grains loose in tray and cemented with ash matrix devitrified to clay minerals; porphyritic.

3170′-3180′ Hematite=trace; smectite=3 percent-4 percent; zeolite=trace.

3180′-3190′ Hematite=trace; smectite=1 percent-2 percent; zeolite=trace.

3190′-3270′ **DEBRIS FLOW/CONGLOMERATE:** Multicolored; varies between hues of moderate red brown to dusky yellowish brown to grayish green; common upper coarse to upper medium grained; poorly sorted; subangular; cemented with clay and trace calcite and meteoric water derived hematite; abundant Basalt Andesite fragments; hematite + limonite appears to be secondary minerals.

3190′-3200′: Hematite=4 percent; smectite=1 percent.

3200′-3220′: Calcite= trace; hematite=2 percent; smectite=1 percent.

3220′-3240′: Calcite= 1 percent-2 percent; hematite=trace; smectite=2 percent.

3240′-3260′: Calcite= trace; hematite=2 percent; smectite=trace.

3260′-3270′: Calcite= trace; hematite=2 percent; smectite=trace.

3270′-3290′ VOLCANICLASTICLASTIC TUFF: Blackish red; moderate hard; friable to rubbly matrix; devitrified to clay minerals + hematite; plagioclase matrix; some scoriaceous fragments; trace biotite phenocrysts; hematite origin is probably a mix deuteric and meteoric in origin.

3270′-3280′: Calcite= 2 percent; hematite=6 percent.

3280′-3290′: Hematite=5 percent; smectite=1 percent.

3290′-3300′ VOLCANICLASTICLASTIC TUFF: Generally as above; possible flow top for underlying Basalt Andesite lava/tuff flow; trace 4mm thick silica amygdale fill; trace smectite; 5 percent hematite.

3300′-3330′ BASALTIC ANDESITE: Mostly grayish black; hard; brittle; microphyric; blocky irregular cutting habit; some hematitic scoriaceous altered fragments in places; trace possible gouge or slickenside; trace pinpoint calcite at 3310′.

3330′-3360′ BASALTIC ANDESITE LITHIC TUFF: Multi-colored; grayish black; 30 percent moderate red brown; grayish black fragments are hard and tough; red brown fragments are crumbly; trace brecciated and silicified red brown fragment; trace smectite; abundant hematite possibly due to secondary mineral alteration.

3360′-3400′ BASALTIC ANDESITE: Grayish black with 8 percent moderate red hematite fragments in 3360′; hard and brittle; micro-porphyritic; mafic; fracture is irregular to hackly; mottled by deuteric hematite; traces of obsidian lithic clast; minor moderately hard white clay mineral or zeolite; rare white spheres of cryptocrystalline silica or feldspar; occurrence of white clay mineral and silica is possibly either deuteric or possibly a hydrothermal artifact; trace calcite.

3360′-3370′ Calcite=trace; secondary hematite=1 percent.

3370′-3380′ White clay mineral=1 percent.

3380′-3390′ Calcite=trace; secondary hematite=trace; white clay mineral=2 percent.

3390′-3400′ Calcite=trace; secondary hematite=trace; white clay mineral=trace.

3400′-3500′ BASALTIC ANDESITE: Grayish black with 15 percent to 30 percent grayish red; grayish black fragments are hard; aphanitic to micro-porphyritic; grayish red hues are from hematite oxidation on fracture surfaces and of some iron rich mineral phases; traces of autobrecciation; rare quartz or feldspar filling amygdale material as rough spheroids; minor white clay mineral or zeolites; trace soft green mineral or clay mineral; rarely traces of calcite.

3400′-3410′ Calcite=none; hematite=2 percent; white clay mineral=1 percent.

3410′-3420′ Calcite=none; hematite=4 percent; white clay mineral=2 percent.

3420′-3430′ Calcite=none; hematite=4 percent; white clay mineral=2 percent.

3430′-3440′ Calcite=none; hematite=4 percent; white clay mineral=3 percent.

3440′-3450′ Calcite=trace; hematite=3 percent; white clay mineral=2 percent.

3450′-3460′ Calcite=none; hematite=3 percent; white clay mineral=2 percent.

3460′-3470′ Calcite=trace; hematite=3 percent; white clay mineral=3 percent.

3470′-3480′ Calcite=trace; hematite=3 percent; white clay mineral=3 percent.

3480′-3490′ Calcite=none; hematite=1 percent; white clay mineral=2 percent.

3490′-3500′ Calcite=trace; hematite=1 percent; white clay mineral=1 percent.

3500′-3550′ BASALTIC ANDESITE: Grayish black for 3510′ sample and mostly grayish red from hematite staining alteration for sample from 3510′ to 3550′; 3510′ is dense lava; samples from 3510′ to 3550′ are probably more of lapilli tuff with the fragments will fused or agglutinated; very hard, brittle with high tenacity; plagioclase-rich matrix; hematite appears mostly primary; trace calcite as fracture-fill; white fragments of a mix of white clay minerals or zeolite and silica or feldspar orbs as amygdale fill in the tray; at 3520′ a green mineral with a hardness of 4.

3500′-3510′ Calcite=none; hematite=1 percent; white clay mineral=1 percent.

3510′-3520′ Calcite=trace; hematite=7 percent; white clay mineral=3 percent.

3520′-3530′ Calcite=trace; hematite=8 percent; white clay mineral=3 percent.

3530′-3540′ Calcite=trace; hematite=6 percent; white clay mineral=2 percent.

3540′-3550′ Calcite=trace; hematite=7 percent; white clay mineral=2 percent.

3550′-3600′ BASALTIC ANDESITE TUFF: Grayish black with 30 percent grayish red hematite washed fragments; hard with good tenacity; mottled; probably lapilli-sized fragments agglutinated and fused together; minor phenocrysts of biotite; trace calcite mostly as pinpoint occurrence; trace white clay mineral or zeolite fragments that are somewhat intermixed with massive silica or feldspar as amygdale; rare green mineral with a hardness of 4.

3550′-3560′ Calcite=none; hematite=1 percent; white clay mineral=1 percent.

3560′-3570′ Calcite=trace; hematite=7 percent; white clay mineral=3 percent.

3570′-3580′ Calcite=trace; hematite=8 percent; white clay mineral=3 percent.

3580′-3590′ Calcite=trace; hematite=6 percent; white clay mineral=2 percent.

3590′-3600′ Calcite=trace; hematite=7 percent; white clay mineral=2 percent.

3600′-3670′ BASALTIC ANDESITE TUFF: Generally as above; rare obsidian clasts; decreasing white clay mineral; traces of pinpoint calcite; no veining or strong hydrothermal overprint noted.

3600′-3610′ Calcite=trace; hematite=3 percent; white clay mineral=trace; zeolite=trace.

3610′-3620′ Calcite=none; hematite=4 percent; white clay mineral=trace.

3620′-3630′ Calcite=none; hematite=4 percent; white clay mineral=trace; smectite/chlorite=trace.

3630′-3640′ Calcite=none; hematite=6 percent; white clay mineral=none.

3640′-3650′ Calcite=none; hematite=6 percent; white clay mineral=none.

3650′-3660′ Calcite=trace; hematite=7 percent; white clay mineral=none.

3660′-3670′ Calcite=trace; hematite=7 percent; white clay mineral=none.

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3670-3720 BASALTIC ANDESITE: Grayish black; hard with good tenacity; somewhat mottled; microphyric to aphanitic; no significant hydrothermal overprint noted; no veining or secondary mineralization noted beyond some traces of calcite as pinpoint occurrence.

3670′-3680′ Calcite=trace; hematite=1 percent.

3680′-3690′ Calcite=trace; hematite=trace.

3690′-3700′ Calcite=none; hematite=trace.

3700′-3710′ Calcite=trace; hematite=trace.

3710′-3720′ Calcite=trace; hematite=3 percent.

3720′-3800′ BASALT ANDESITE TUFF: Brownish black with some grayish red; hard and dense; tough tenacity; abundant to common late stage hematite alteration which most likely occurred during the cooling of the volcanic rock; tuffaceous and somewhat mottled; minor welding, but appears mostly lava-like; trace pinpoint calcite; traces of chlorite probably associated with alteration adjacent or in amygdales; chlorite indicate an increase in the isograd; no veining, fractures or secondary mineralization of hydrothermal origin noted.

3730′-3740′ Chlorite=trace; hematite=5 percent.

3740′-3750′ Chlorite=trace; hematite=4 percent.

3750′-3760′ Chlorite=none; hematite=2 percent.

3760′-3770′ Chlorite=trace; hematite=3 percent.

3770′-3780′ Chlorite=trace; hematite=3 percent.

3780′-3790′ Chlorite=trace; hematite=3 percent.

3790′-3800′ Chlorite=trace; hematite=3 percent.

3800′-3852′ TD BASALTIC ANDESITE TUFF: Grayish black with minor moderate red to grayish red; hard and tough and somewhat dense; minor to common hematite altered fragments probably incurred during the late stage emplacement of lava flow; microphyric, more so for the more mafic fragments; tuffaceous texture with lithic clast commonly showing more preferential hematite alteration; some scoriaceous fragments with vesicles often filled by late stage primary minerals or secondary minerals; rarely cindery ash clay material; trace cryptocrystalline felsic or silicic spheroid crystal shards as amygdale fill; trace clear to translucent light green mineral with a hardness of 3;

trace chlorite/smectite washed grains; no significant secondary minerals noted; no obvious veining or fracturing noted.

3800′-3810′ Chlorite/smectite= trace; hematite=3 percent.

3810′-3820′ Chlorite/smectite= trace hematite=3 percent.

3820′-3830′ Chlorite/smectite= trace hematite=2 percent.

3830′-3840′ Calcite=trace; chlorite/smectite= trace hematite=3 percent.

3840′-3850′ Calcite=trace; chlorite/smectite= trace hematite=3 percent.

APPENDIX B:
ISO-2 Rig Test Plan Change

GEOTHERMAL SCIENCE, INC.

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October 6, 2011

Dale Merrick, Project Manger
Canby Geothermal Development Project
P.O. Box 125
Canby, CA 96015
canbygeo@gmail.com

Subject: Basis for Changing ISO-2 Plan from Flow to Injection Test

Dear Mr. Merrick,

During the drilling of ISO-2 last month the decision was made to stop drilling at 3852 ft and run electric-line logs. After these logs were run, a further decision was made to change the plan of running a flowtest to one of running an injection test. This was done because based on the data available at that time, the assessment was that there was little likelihood that the well would be able to flow at a rate and temperature needed for the planned project to be viable.

This decision was made as a result of the integration of the following considerations:

- During drilling there were no recorded losses of drilling fluids. This is suggestive of limited or no permeable fractures having been encountered in the well.
- The history of mud-out temperatures during drilling did not provide any encouragement of the targeted temperatures having been encountered.
- Neither did the drill cuttings offer any encouragement of a target hydrothermal system having been encountered.
- Finally, the open-hold electric log measurements confirmed these prior indicators of limited temperatures and fractured rock.

The injection test was carried out because it provided a cost-effective way to estimate the ability of the rocks encountered by the well to either accept or produce water. This test resulted in an estimate of well injectivity of 1 gallon per minute per psi of pressure change. This is a low value, corroborating the decision to not attempt to run a flow test.

Please let us know if you have any additional questions about this matter.

Sincerely,

Paul Atkinson

Paul Atkinson
Consulting Reservoir Engineer

APPENDIX C:
ISO-2 Rig Injection Test

ISO-2 Rig Injection Test – Canby Geothermal Project

Report By:

Paul Atkinson, PhD.

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Report Submitted to:

Modoc Contracting

P.O. Box 198

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Revision:

Version 2

Date: October 5, 2011

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1	Sept 29, 2011	P. Atkinson	J. Murphy	P. Atkinson	Sept 29, 2011
2	5 Oct 2011	P. Atkinson	J. Murphy	P. Atkinson	5 Oct 2011

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Document Version:	2

INTRODUCTION

This report describes the rig injection test operations and results carried out on the ISO-2 well of the Canby Geothermal Development Project.

The report presents a summary of the rig operations leading up to the test, those during the test, and the data acquired. The data acquired during the test are presented and analyzed. Finally, an estimate of well injectivity is presented.

OPERATIONAL SUMMARY

The well reached a total depth of 3852 ft on September 11, 2011. On September 12 electric line logs were run (Gamma Ray, HDL Resistivity, pressure & temperature.) A liner was run the next day, with the top of the liner hanger at 1273 ft and the liner shoe at 3300 ft (the 13 $^3/_8$" casing shoe was at 1427 ft.) From the top, the liner consisted of 22 blank joints, 23 perforated joints (beginning at 3026 ft), 4 blank joints and 3 perforated joints at the bottom. The bottom portion of the well from 3300 ft to the total depth of 3852 ft was left open hole.

The rig injection test was run on September 14. Open-ended drill pipe was run into the hole to 1126 ft and surface water at approximately 50^{o} F was injected. The rate was increased in a step-wise fashion and surface annulus pressure at the wellhead was measured through one of the 13 $^3/_8$" casing head outlets. During drilling operations this gauge was attached to the standpipe on the rig floor to record pressures at the top of the drill string. However, prior to the injection test it was moved to the wellhead to obtain a more useful measure of surface pressure during the test. The pressures were displayed on a monitor on the rig floor and were also recorded by Pason.

Injection increased until a maximum surface pressure of approximately 350 psig was reached after 27 minutes at an injection rate of 337 gpm. This rate was held for another 25 minutes, at which time the water supply in the tanks ran out and injection was stopped. Figure 1 displays the time series of the digitally recorded data.

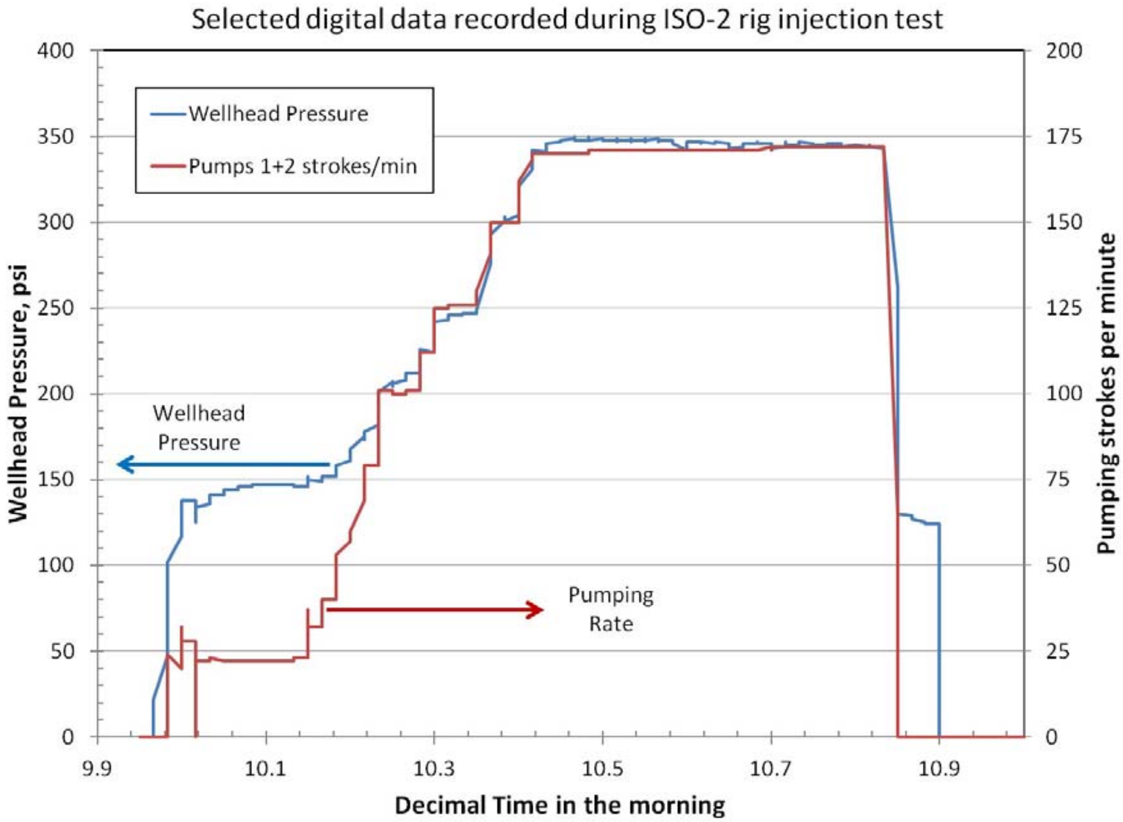

Figure 1 - Digital data for pumping rate and wellhead pressure

After termination of injection approximately 138 barrels of water flowed back out of the well. This flow-back is strongly suggestive of a formation with limited permeability.

Table 1 presents the wellhead pressures and pumping rates read from the data collection screen and recorded manually. This was done by following a process of waiting until the pressure "stabilized" before increasing the flow rate. The pressure was considered to be “stabilized” when it did not vary more than 1-2 psi in either direction for about a minute, and appeared to not be changing significantly. The period to accepted “stabilization” following each new flowrate was typically a few minutes. The pumping rate was reported in strokes per minute and converted to a volumetric rate assuming 80 percent pump efficiency.

	Wellhead Pressure,	**Rate, strokes/ min**	**Rate,**
10:05	137	22	44
10:07	142	22	44
10:10	147	22	44
10:13	146	22	44

	Wellhead Pressure,	Rate, strokes/ min	Rate,
10:14	150	32	63
10:15	152	40	79
10:16	167	60	119
10:17	174	70	139
10:18	181.5	80	159
10:20	205	100	198
10:23	245	125	248
10:28	298	150	297
10:32	347	170	337
10:57	343	172	341

Table 1 - Recorded Injection Test Parameters

ANALYSIS

Figure 2 presents the recorded data as a graph of wellhead pressure versus injection rate (open diamonds). Also shown as closed diamonds are the final four rates which per the discussion below are hypothesized to represent a normal wellhead injectivity curve.

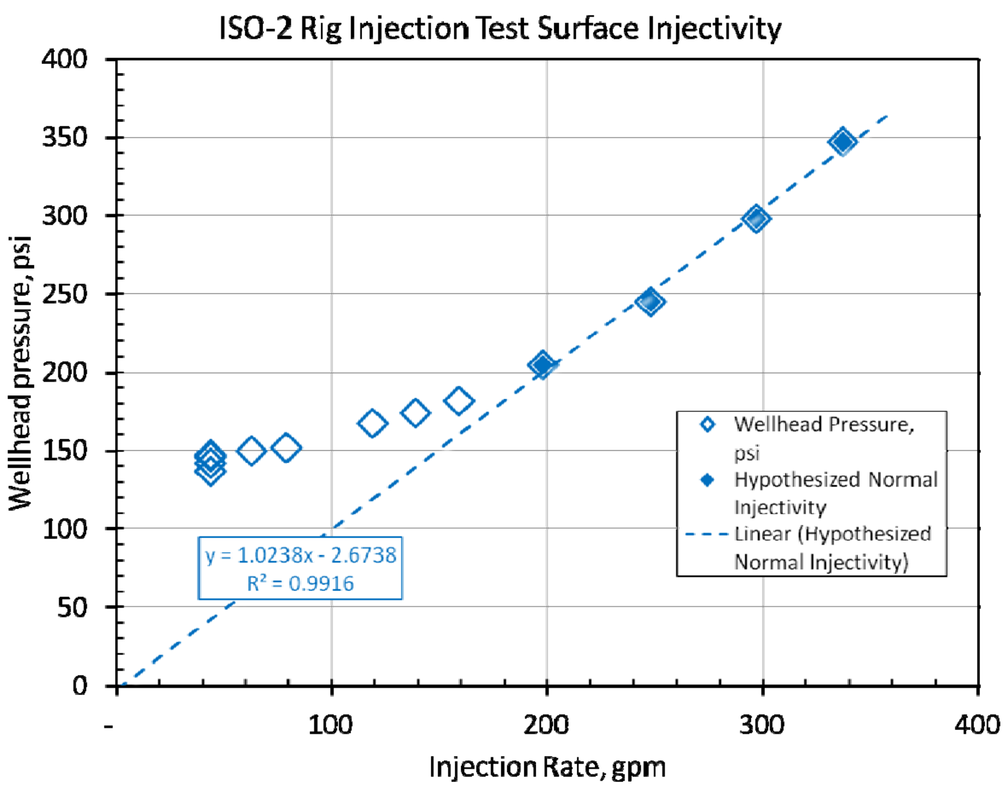

Figure 2 - ISO-2 Surface Injectivity

Two calculations were made to assess the nature of the varying slope of the surface injectivity results in Figure 2. This was done because the nature of such data during injection tests tends to be linear with the possibility of two different slopes, with a decrease in slope at higher rates (in contrast to the behavior seen in Figure 2). The working hypothesis being tested was that the approximate linear trend observed for the four data points beginning with the 198 gpm rate was due to the cold surface injection water beginning enter the formation. The increase in slope would be due to the fact that water entering the formation at approximately 150° F was replaced by higher viscosity water at approximately 50° F. This would occur after the water initially contained in the volume of the well was displaced by the colder injected water.

The first calculation was that of the capacity of the well experienced by the injecting liquid if it exits the bottom of the open hole. This capacity was calculated to be 38 bbl to the top of the

9 $^{5}/_{8}$″ liner and 354 bbl to TD. The second calculation was made to estimate the cumulative injection of liquid over the course of the test: 31 bbl at the end of the 198 gpm rate and 116 bbl at the end of the highest rate shown on Figure 2. The results of these calculations are generally consistent with the hypothesis that cold water may have begun entering the formation around the time of the ~200 gpm rate, and that this and the higher rates occurred with, the cooler, higher (by a factor of three) viscosity water. This explanation is not completely satisfying, and there were probably other physical effects occurring. This is the nature of a short rig test like the run for ISO-2 – the test is short and simple and the results are able to provide an indication of well performance, but not one that is necessarily technically rigorous.

Figure 2 presents the wellhead pressures for the four short-duration rates of 198 gpm and higher as closed diamonds. These results are an approximation of the well injectivity interpreted to have been experienced during the rig test. The figure includes a curve fit of the four higher rate values. This equation can be considered as a first approximation of the well injectivity, with an estimated injectivity index of approximately 1 gpm/psi. It needs to be stressed, though, that this result has been derived from a very short test during which most individual rates only occurred for a few minutes. Thus, longer-term injection in the well might have different characteristics. However, it is clear that the overall injectivity of ISO-2 is limited.

APPENDIX D:
ISO-2 Reservoir Report

ISO-2 Reservoir Report – Canby Geothermal Project

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SUMMARY

This report provides a brief description of the reservoir encountered by the ISO-2 well of the Canby Geothermal Development Project. The discussion is based in part on the three reports which describe the drilling, geology and rig injection testing of the well.

The pressure and temperature measurements made in the well following the completion of drilling are described first. Then, the evidence indicating that no significant permeability or fractures were encountered is reviewed. The basis for concluding that the well did not encounter the hypothesized hydrothermal system is presented next. Finally, a set of recommendations for follow-up assessment of the well are provided.

INTRODUCTION

This report provides a brief reservoir engineering summary of what was learned about a targeted potential hydrothermal system as a result of the drilling and rig testing of the ISO-2 well of the Canby Geothermal Development Project.

The data and analysis which underlie this report are contained in the following three reports:

1. "CANBY ISO-2 Final Report", prepared by Geothermal Resource Group, Bill Rickard, PE.
2. "Geology And Well Description of the Iso-2 Geothermal Production Test Well at Canby, Modoc County, Northeast California," by Joe LaFleur and Mike Krahmer, Geologist Extraordinaire & Associates, LLC, October 2011.
3. "ISO-2 Rig Injection Test – Canby Geothermal Project," by Geothermal Science, Inc., October 5, 2011.

The target of the ISO-2 well was a hydrothermal resource considered to potentially lie below the site. The well did not appear to find any such resource. This conclusion is based on considering the elements of a viable hydrothermal resource, and whether or not the ISO-2 data support the presence of such a system.

First, the pressure and temperature measurements made in the well will be presented and briefly discussed. Then, the evidence for the presence of fracturing or permeability will be reviewed. Finally, there will be a discussion of whether these data and the associated analysis support the presence of a hydrothermal system in the rocks encountered by ISO-2 – with the conclusion that they do not.

A final section will briefly present a series of recommendations for following through on the investment made in the well to better characterize the subsurface conditions encountered and as a result have a better basis for considering future activities or investments in the well and project.

TEMPERATURE AND PRESSURE MEASUREMENTS

Two electric line logging runs were made. They are described and discussed in the geology report. The first run was begun 14.5 hours after circulation stopped and included temperature, pressure and gamma ray tools. Only the temperature and pressure results are discussed in this report.

Figure 1 presents the results of the two temperature profiles logged. The 2.4 Fahrenheit degree increase between the down- and up-runs at the bottom is due to the fact that the tools sat on bottom for ten minutes to measure temperature build-up. The geology report contains some discussion about possible interpretations of these two profiles. In summary:

- With a maximum measured temperature of 170 ^{O}F, the well is not very hot.
- It is likely to heat up over time. But it is not likely that this will be enough to meet the goals of the project planned for the well.
- A recommendation presented in the geology report and reiterated in this report is that the well be surveyed again after it has had time to warm up.

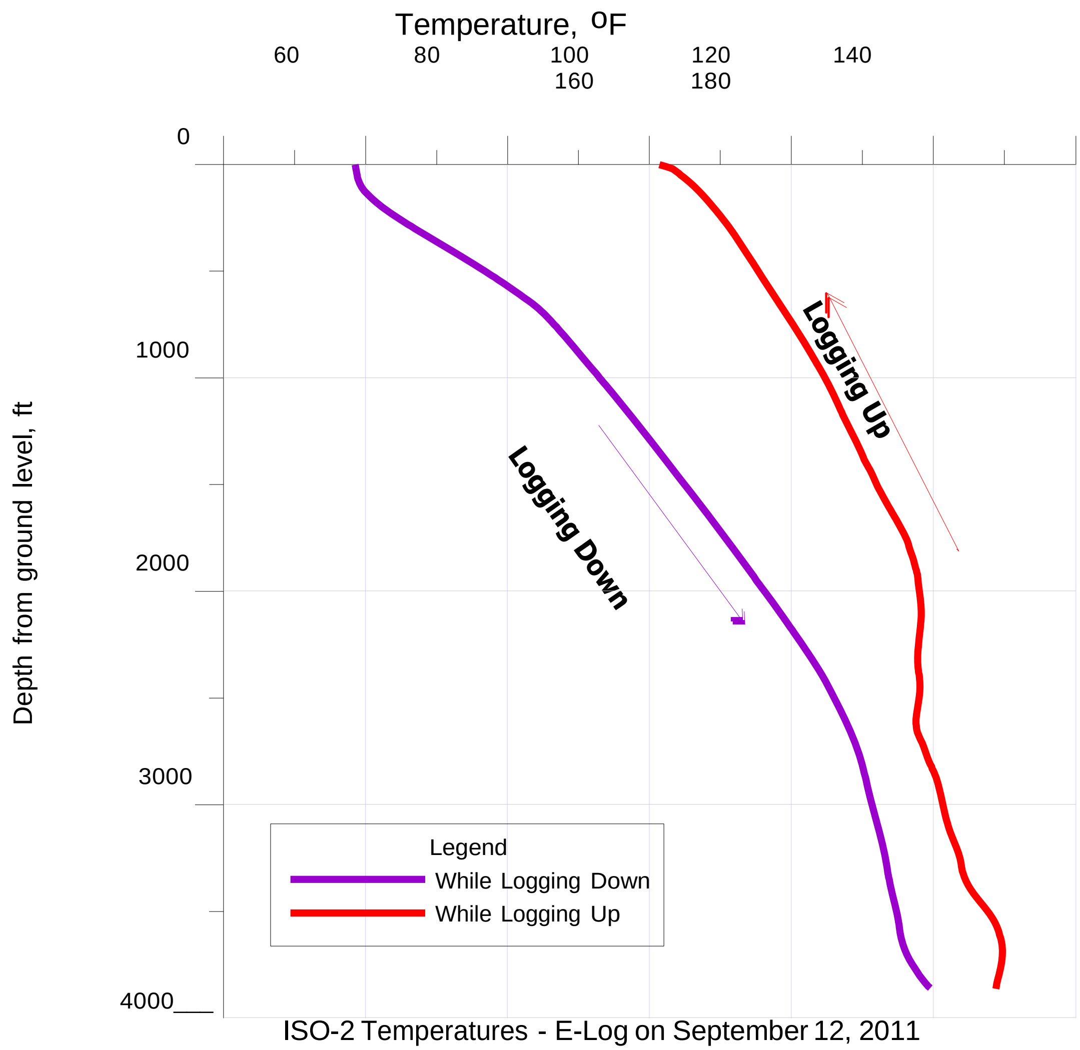

Figure 1 – ISO-2 Temperature Measurements, September 12, 2011

Figure 2 presents the results of the two pressure profiles logged. Units of pressure are not contained in the .las file of the logging data. These units are interpreted to be psig because the value at ground level of the down run is 10.7. a value too low to be psia. The 14 psi pressure drop at the bottom of the profiles is again due to the fact that the tool sat on bottom for ten minutes.

The pressures measured at ground level were 10.7 psig for the down-run and 13.2 psig for the up-run. These indicate that the inter-connected rock pore or fracture volume that the well intersects is in approximate hydrostatic equilibrium with a column of water whose liquid level is at ground level.

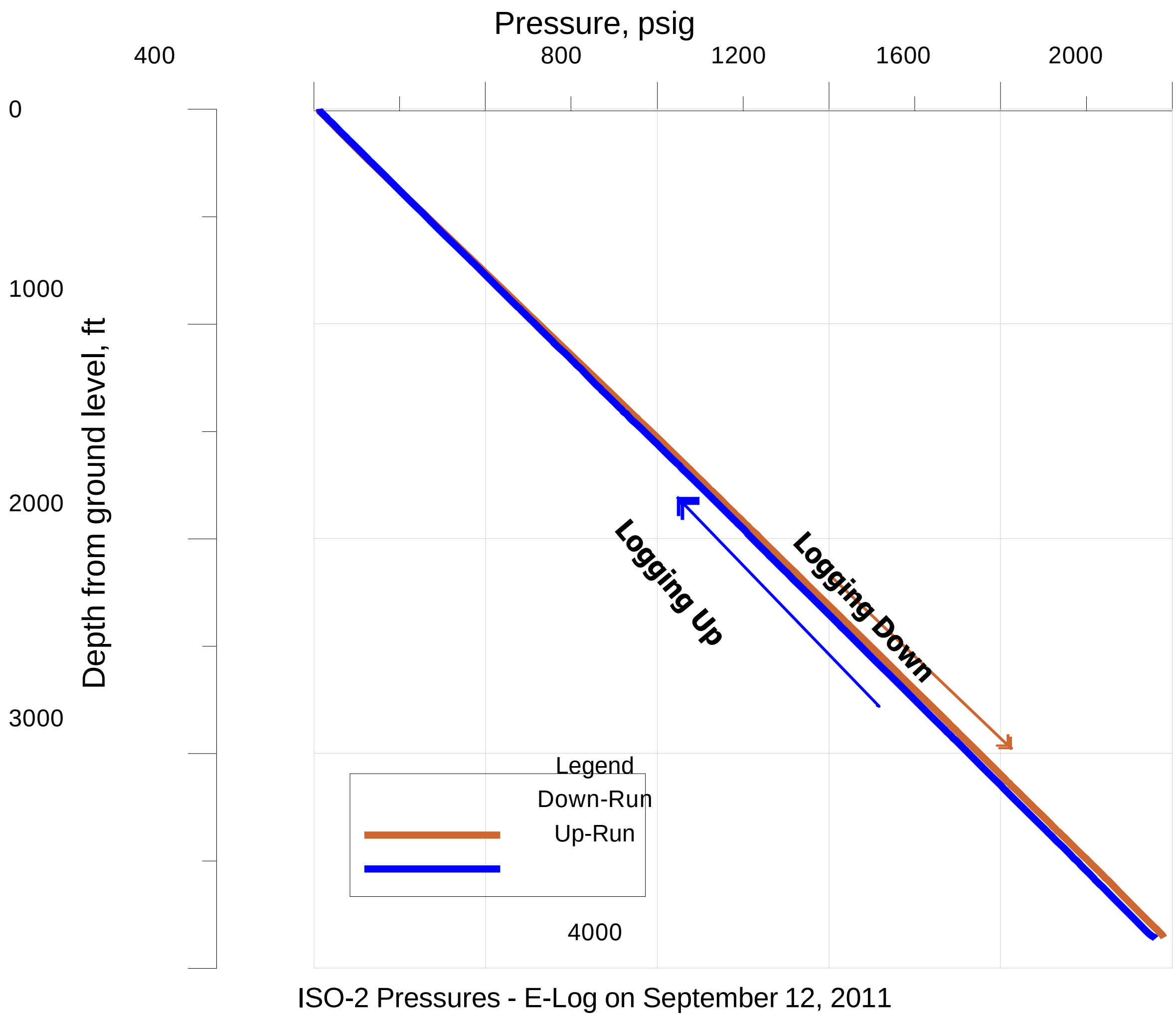

Figure 2 - ISO-2 Pressure Measurements, September 12, 2011

PERMEABILITY AND FRACTURES

The well does not appear to have encountered permeability that would normally be associated with the kinds of fractures encountered in a hydrothermal system. This conclusion is based on two observations:

1. No lost circulation was observed during the drilling of the well, even though mud weights were higher than hydrostatic.
2. The well injectivity is below that which would normally be considered acceptable for production of geothermal fluids for a project as proposed. Additionally, following the
3. 3.. termination of injection during the rig injection test, 138 barrels of water flowed back out of the well over a 23 minute period.

It is in theory possible that the reason the well injectivity is low is because drilling mud damaged the formation by blocking the pore space of the formation adjacent to the well. This is unlikely to be the reason why the injectivity was measured at a low value, because in this type of geologic environment productivity in commercial wells normally comes from fractures, not through the pore space of the rock medium.

WAS A HYDROTHERMAL SYSTEM ENCOUNTERED?

Probably not. This question is thoroughly discussed in the geology report submitted for the well and referenced above. The following two quotes from the report summarize key elements of this conclusion.

> The result of the well was that it did not identify a higher temperature resource at depth. The cuttings did not contain secondary mineralization typical of hydrothermal systems, past or present. The temperature of the hole, as suggested by recorded mud- in versus mud-out temperature variations, did reflect the shallower resource zone as was encountered in the ISO-1 well, but it did not offer encouragement for a higher temperature resource at depth.
>
> Regardless of whether or not the target fault was actually encountered, it does not appear to be a major conduit for higher temperature hydrothermal fluids. There was nothing in the cuttings or temperature log that suggests an "upflow fault" is close at hand.

RECOMMENDATIONS

This section presents two recommended activities that will help in any follow-up assessment of the ISO-2 well and hypothesized hydrothermal system:

1. Wait for the well to heat up and then run pressure and temperature static surveys. A four-week warm-up period will likely be enough to get a good indication of static conditions. A second set of surveys after a longer period of warm-up would be optional and allow for confirmation of the first set of surveys. Avoid injecting into the well before the warm-up measurements are completed. It would also be good to complete the warm-up assessment before proceeding to the next activity.
2. Pump fluid out of the well over a period of time in an attempt to get representative formation fluids for chemical analysis. This will likely require removing a few times more volume of fluid than was injected to get representative formation fluid (about 300 bbl of water was injected during the rig injection test.)

An additional, optional assessment of the well would be to run an injection and fall-off test with downhole instrumentation or some other means of measuring the pressure response in the well. This could also be done by pumping the well and monitoring the downhole pressure build-up (there are trade-offs of cost vs. ease of interpretation.) The objective of doing such a test would be to assess the extent to which limited injectivity is:

- due to an absence of good permeability or encountered fractures; or
- also due to the formation having been obstructed by the drilling mud.

An analysis of whether there may be formation damage due to the drilling mud has not been carried out as part of the preparation of this report.

APPENDIX E:
ISO-2 Pressure Temperature Survey